Inside the secrets of the icy **Kuiper Belt** p. 30

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April 2010

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Fifty years after Frank Drake quantified life in our galaxy, here's where we stand p. 24

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Recent discoveries have helped astronomers narrow down variables in the search for extraterrestrial civilizations.

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Bob Berman on why astronomy is so hard p. 16

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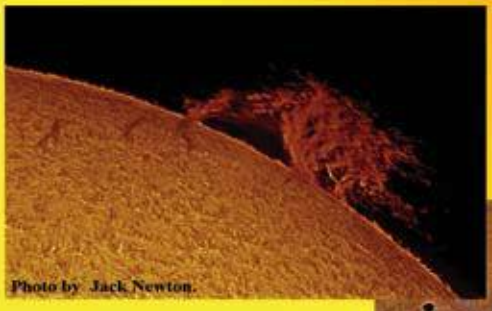
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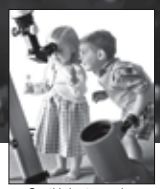
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The magazine cover headline called the $1995 **Astro-Tech AT106** 4.2" ED triplet refractor "A Scope Too Good To Be True." The 4-page review inside said the AT106 "provides all the benefits of a first-class 4-inch apo but without the premium price." Even better, a Limited Edition model with the same gorgeous FPL-53 triplet optics (simply fewer bells and whistles) *is only $1495.*

The magazine's 4-page review of Astro-Tech imaging scopes said that the **Astro-Tech AT8IN** 8" f/4 imaging Newtonian, "with its 8-inch aperture and $449 price tag, wins the biggest-bang-for-the-buck award . . . there's a quality to this scope that seems contradictory to its relatively low cost."

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Links to all products in this ad are at www.astronomics.com/ast0410.

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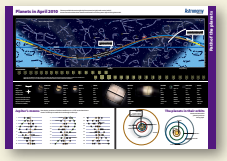

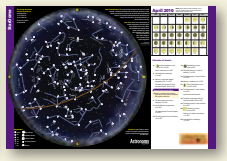

Path of the planets and StarDome.

Cover illustration: Lynette Cook for *Astronomy*

ON THE COVER

Astronomers are using new research with the Drake Equation to help narrow down how many planets in the Milky Way may harbor advanced civilizations.

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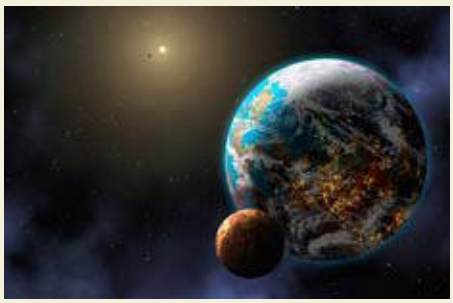

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This Month in *Astronomy*

by David J. Eicher

Astronomy partners with Northeast Astronomy Forum

The 19th annual Northeast Astronomy Forum and Telescope Show (NEAF), the nation's largest telescope event and meeting of amateur astronomers, will be held April 17 and 18, 2010, in Suffern, New York, outside New York City. The meeting takes place at Rockland Community College and will feature an A-list of exciting speakers, more than 100 vendors, and hundreds of telescopes and accessories on display. The event offers the best opportunity all year for amateur astronomers to get out and see the exciting equipment being developed for our hobby.

And now *Astronomy*, the world's largest magazine on the subject, proudly announces a partnership with the Rockland Astronomy Club to help sponsor this terrific event. "We are excited to have *Astronomy* involved in the meeting because the magazine understands the market and the need to bring a younger audience into the hobby," says Alan Traino, NEAF's chairman. The event will feature stellar speakers, including Alex Filippenko of the University of California at Berkeley, Amy Mainzer of NASA's Jet Propulsion Laboratory, Philip Goode of the Big Bear Solar Observatory, *Astronomy* Contributing Editor Mike Reynolds, Chris Lintott of BBC's *Sky at Night* magazine, Clear Sky Clock creator Attilla Danko, and solar observer Erica Rix.

A dazzling array of equipment will be on display, offering one of the best opportunities to see new and innovative gear and to try out and inspect telescopes and accessories. All the major manufacturers will be there — Celestron, Explore Scientific, Meade, Orion, Questar, Stellarvue, Takahashi, Tele Vue, and Vixen — as well as dozens of smaller companies. Imagers will be particularly keen on checking out equipment from the camera companies such as Apogee, Atik, Canon, the Imaging Source, Finger Lakes Instrumentation, Quantum Scientific Imaging, Santa Barbara Instrument Group, and others.

A significant event precedes NEAF, as in the past, with the NorthEast Astro-Imaging Conference (NEAIC) 2010, held at the same location. It features the latest in imaging equipment and spectacular photos of planets and deep-sky objects. On April 15 and 16, NEAIC attendees will present many talks, including a Thursday night remote imaging session supervised by Tim Puckett. Poster sessions will share results from the community of astroimagers, and at least two dozen companies will display equipment. You won't want to miss it!

And NEAF itself will feature many things to do. There will be astroimaging workshops, daily solar observing, STARLAB planetarium shows, classes on amateur astronomy for beginners, and an emphasis on space and astronomy for kids. Traino expects more than 3,000 amateur astronomers to attend NEAF and, in addition, expects 2,000 youngsters and their families to participate from the New York City area. This adds a new dimension this year — developing the future of the hobby.

For more information about NEAF, please visit their official web site at www.rocklandastronomy.com/neaf.htm.

Stay tuned for further news involving NEAF and *Astronomy* magazine!

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 38, Number 4

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How to blow a cosmic bubble

A massive star's fierce stellar wind sculpts the intricate Bubble Nebula (NGC 7635) in Cassiopeia. Meanwhile, that star's blazing ultraviolet radiation excites atoms in the surrounding interstellar medium and causes them to glow. The star, which is cataloged as BD +60°2522, lies to the right and a little above the Bubble's center. It is a Wolf-Rayet star, one of only a few hundred discovered in our galaxy. Stars like BD +60°2522 contain up to 20 times the Sun's mass. Yet they quickly waste away as their winds blow trillions of tons of material into space each second. BD +60°2522 likely will explode as a supernova within the next million years. T. A. Rector (University of Alaska, Anchorage)/H. Schweiker (WIYN)/NOAO/AURA/NSF

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by Karri Ferron

GETTING TO KNOW

Dimitrios Psaltis

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Assistant professor of astronomy and physics at the University of Arizona

Favorite research topic: Right now, I am interested in what goes on inside neutron stars, some of the densest objects in the universe. The most powerful explosions and strongest gravitational fields all happen on neutron stars. Are their centers really made of neutrons? Unconfined quarks? Other particles? I am working on ways to tell them apart.

Basis for your interest in the world's sustainable energy problem: I see sustainable energy as the world's most pressing problem. We're running out of atmosphere and out of oil, and now is the time to attack this issue. As a scientist, a citizen, and a mom, I feel like I need to make a contribution. I truly believe that we need to make serious investments in electric cars and develop nuclear and solar energy.

Coolest things you've done in your career: It was very exciting to measure for the first time the radii of several neutron stars and the pressure of matter above nuclear density. I worked out the signatures of quantum electrodynamics on magnetars. I also predicted how big the black hole at the center of the Milky Way should look in different wavelengths, which astronomers are measuring these days.

Goals for the next 5–10 years: There are many fascinating problems ahead of us, and I will go wherever they take me. Perhaps, after exploring the properties of ultradense matter, I will work on vacuum energy.

One question about our universe you would like answered: I think the biggest unknown right now is dark energy. We can't make consistent sense out of our accelerating universe and how vacuum energy can be responsible for it. We all want to know the answer!

Favorite things to do in your spare time: I love sports — marathons, triathlons, diving, hiking — or anything involving the outdoors, being active, and seeing new things.

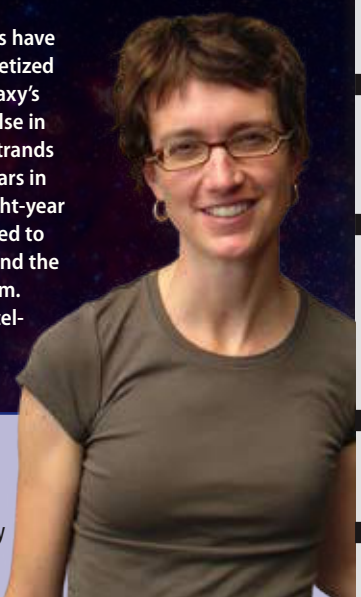
Astroideas *What are the big ideas about our galaxy's center?*

One ongoing area of research is how massive stars can form in the extreme environment of the Milky Way's center. We observe massive stars throughout the central few hundred light-years of the galactic core as well as within less than a light-year of the supermassive black hole.

A Hubble Space Telescope NICMOS (infrared) survey of the galactic center has revealed glowing ionized gas heated by massive stars and many massive stars themselves. This survey provides a new census of the stars near the galactic center and allows astronomers to better characterize the stellar content and mode of star formation in the region.

Another area of study is the nature of the magnetic field in the galactic center. For 3 decades, radio observations have revealed an unusual set of magnetized filamentary structures in our galaxy's core that aren't seen anywhere else in the Milky Way. Those magnetic strands can extend up to tens of light-years in length, but only fractions of a light-year in width. They appear to be related to dense clouds of interstellar gas and the massive stars that illuminate them. Pockets of electrons could be accelerated along the filaments causing the radio emission.

Courtesy Cornelia C. Lang; background: NASA/ESA/SSC/CXC/STScI



Cornelia C. Lang

Assistant professor of astronomy and astrophysics at the University of Iowa in Iowa City

A DAY IN THE LIFE OF ...

Courtesy Alyssa Goodman

Alyssa Goodman

Professor of astronomy at Harvard University and research associate of the Smithsonian Institution

7 A.M. Help my 12-year-old daughter get ready for school.

8:30 A.M. Prepare notes for "Journal Club" presentation later today.

9:30 A.M. Respond to e-mails.

11 A.M. Give my Journal Club presentation about a paper on the "inevitable future" of a dense blob of gas that the paper's authors say will collapse to form a star in 100,000 years.

12:30 P.M. Host a group meeting with students and postdoctoral fellows. Individuals describe their ongoing work to the group and receive feedback and input. Today, a Harvard College student talks about his thesis on stellar winds' impact on star-forming regions and a graduate student shares his discovery of how to define the gaseous precursors of stars like the Sun.

3 P.M. Meet with the department administrator to help a consultant get paid on time. Together, we are working on starting a public outreach program involving Microsoft's WorldWide Telescope program.

4 P.M. Meet with a colleague's grad student, plus my grad student, about a potential collaboration on beautiful new stellar extinction maps of the Taurus region.

5 P.M. Meet with a visitor giving tomorrow's IIC Seminar on "Linked Data." I am the founding director of the IIC, which stands for Initiative in Innovative Computing.

6 P.M. Drive the IIC speaker to a dinner in his honor. Bump into four other tables of colleagues (not that common!) at the restaurant. Chat with colleagues who've returned from a meeting on extrasolar planets at the Vatican Observatory.

8:40 P.M. Help my daughter with science homework on atmospheric pressure. Then watch *Pinky and the Brain* with her.

9:45 P.M. Answer e-mail, chat with my husband, read materials for tomorrow's meetings, and write a recommendation letter.

Astro**influences**

How did you become interested in astronomy?

David Friedlander (NASA)

Thayne **Currie**

NASA Postdoctoral Fellow at Goddard Space Flight Center in Greenbelt, Maryland

I grew up on a farm in rural Kansas and could see the night sky filled with stars, uncontaminated by city lights. I pored through books on the solar system, stars, and constellations. I had the properties of all the solar system planets and the main stars in Orion memorized in fine detail. Some days I spent more time in the library reading about astronomy than I did in class.

Because my school had few enrichment opportunities, my interest in astronomy faded by high school and took a back seat to other interests, especially tennis. In fact, I went to college primarily for athletics, not academics.

In college, my outlook on the future quickly changed. Enrolling in a survey course in astronomy reignited my interest in the subject. I relinquished my full-ride athletic scholarship and focused on astronomy. The physics department offered me astronomy research opportunities that I quickly accepted.

In graduate school, my focus sharpened to studying planet formation and extrasolar planets. Besides appealing to me on a visceral level, I've found that this research provided a natural outlet for my aptitude for mathematical reasoning and my burning philosophical questions, such as "How did Earth and the rest of the solar system get here?" and "Are solar systems like ours common or rare?" Although I often spend long hours doing research, I rarely feel as if I'm working because I like what I do.

OUR TURN

Roger **Blandford**

Director of the Kavli Institute of Particle Astrophysics and Cosmology (KIPAC) and professor at Stanford University in California

Courtesy Roger Blandford; pulsar: NASA

"The largest soluble problem about the universe is to identify dark matter."

What caused you to focus your research on the high-energy area of astronomy?

Well, when I was a first-year undergraduate student at Cambridge, I joined the Astronomy Society and heard Tony Hewish talk about pulsars, which he and Jocelyn Bell had just discovered. I thought these stellar remnants were amazing. Later, as a first-year graduate student, my adviser, Martin Rees, introduced me to double radio sources. At first I thought they were made by pulsars, but with research I soon began to associate them with massive black holes. After that, one problem led to another.

What research going on at KIPAC are you most excited about?

It has to be the Fermi Gamma-ray Space Telescope, which is working superbly, making weekly astrophysical discoveries and setting important constraints, so far, on the properties of dark matter. My colleagues also have done great work on exoplanets, clusters of galaxies, the microwave background, pulsars, and active galactic nuclei. I am excited by the way computational astrophysicists are solving puzzles that have resisted "pencil and paper" approaches for decades. And you can add to this all the great progress on designing some challenging new telescopes that will be used to study dark matter and dark energy, cosmic inflation, and high-energy particles. It's all exciting.

What question about our universe would you like answered in your lifetime?

I think the largest soluble problem about the universe is to identify dark matter. There are many approaches to follow, and I look forward to seeing which of them finds the solution first.

What are some of the coolest things you've done in your career so far?

Personal highlights from my work and research include learning about the first binary pulsar; the first gravitational lens; and Supernova 1987A, the first nearby supernova in hundreds of years. Also, seeing the Hubble Deep Field for the first time, observing with the first Keck telescope, and seeing the first data from Fermi.

For me, novelty and discovery are cool. I have had the privilege of working with some wonderful mentors, contemporaries, and students at a time of unprecedented discovery about the universe, what it contains and how it works. Amazingly, the party is still going on.

Look, but don't steal

I just returned from Namibia and was surprised to learn that the capital, Windhoek, features an attraction called Meteorite Fountain. It is a display of about 30 similar basketball-sized meteorites. They are nickel-iron, and one was cut and polished.

The meteorites, mounted on small pedestals, are on display right on the street, without any cover or barriers. I figure at current prices for meteorite specimens, several million dollars worth of meteorite material just sits there. I went to a restaurant nearby at night, and when I came out at 9:30 P.M. the area was empty. It's a wonder no one's ever stolen anything.

I figured these meteorites must have been the result of a spectacular bolide. The fountain was an amazing display. — **Tom Geisler,** Hayward, California

Meteorite Fountain, an attraction in the capital city of Windhoek, Namibia, contains more than 30 meteorites freely available for the public to look at and even touch. David Overstreet

Texas toasts Bob Berman

My thanks to all the staff for publishing such an interesting and educational magazine. Although I enjoy every single page, my personal favorite has become Bob Berman's "Strange Universe."

Every month, I find myself cutting his column out and filing it away for future reference. Berman has a unique gift for clearly and humorously explaining the more complicated aspects of the universe to those of us who lack his incredible knowledge. He brings great pleasure to so many who view his work. Thank you! — **Scott Abram,** Hurst, Texas

Far out observations

I always feel a great sense of accomplishment when an observing plan forms and unfolds under a starry sky.

In 1993, back when Pluto was still a major planet, my 20-inch telescope split Pluto and its moon Charon reasonably well at 509x in moments of good seeing. Charon was near maximum separation, about 1" from Pluto, with good elevation above the horizon at midnight that memorable summer night.

In the past 15 years, astronomers have discovered many objects in the Kuiper Belt, of which Pluto is the brightest member (at about 39 astronomical units [AU] away, or 39 times the distance from Earth to the Sun). The next faintest trans-Neptunian objects, and members of the Kuiper Belt, are Makemake and Haumea, residing at distances of about 46 AU and 43 AU, respectively.

With charts and photos on the top step of a 12-foot ladder, I centered Makemake in my eyepiece June 13, 2009. Two weeks later, I was able to track down Haumea. Neither observation required exceeding 350x.

Because the International Astronomical Union also considers Ceres a dwarf planet, last June brought the total dwarf planets I've observed visually to four: Pluto, Ceres, Makemake, and Haumea. Eris — though I prefer its discovery name of Xena — is even fainter, and more elusive. I'll wait a few months and see if I can extend my visual reach all the way out to 68 AU. — **Steven Aggas,** Gold Canyon, Arizona

Practicing good examples

For years I've been an amateur astronomer, and I have enjoyed your magazine now for quite a while. Professionally, though, I'm in a different branch: As a sociologist, I specialize in gender and equal opportunities.

Recently, my colleagues and I were looking for good practices of gender-balanced scientific publications, and I realized that your "Astro Confidential" section is a very nice example. We are currently training around 700 European scientists about gender and showing them your magazine as a "good practice example." Keep up the wonderful work! — **Katrien Van der Heyden,** Berchem, Belgium

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Webtalk

Springtime observing for small telescopes

In this video, *Astronomy* magazine Senior Editor Michael E. Bakich presents objects you can see this spring using a small telescope. Highlights include the star Mizar, spiral galaxy M101, open cluster M67, and the Sombrero Galaxy (M104).

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"Cosmology 101: Big Bang"
Associate Editor Liz Kruesi explains the two incorrect ideas that cause the confusion about the Big Bang.

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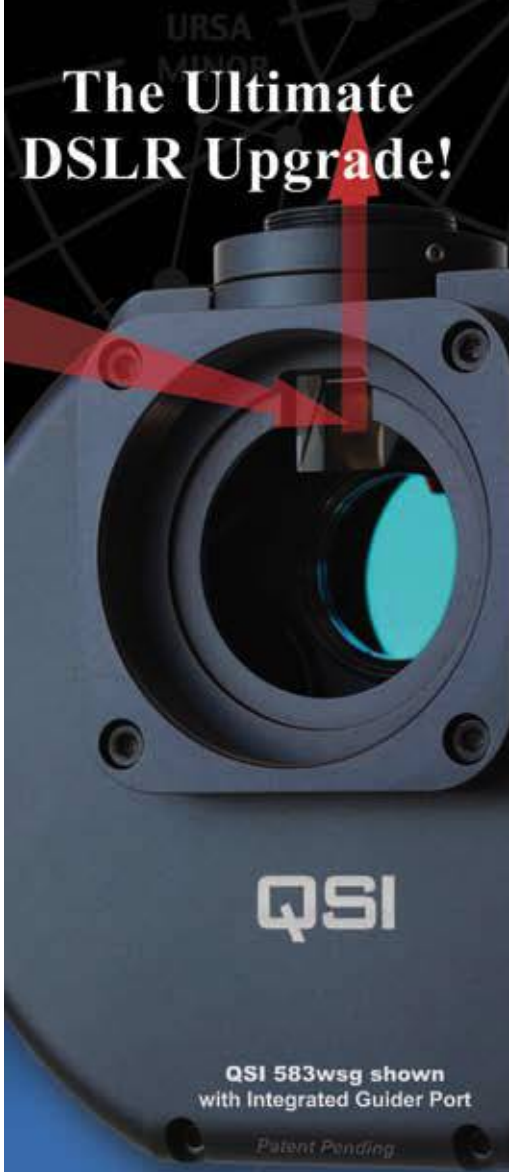

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Strange Universe

by Bob Berman

Why would anyone quit astronomy?

A variety of complaints can make people give up on our beloved hobby.

They find me somehow. "Can you help us set up our new telescope?" asks a stranger's voice over the phone. If they live nearby, sure. But if I run into them again and ask how astronomy's going, there's a familiar response: "We used the scope only once more."

"Keep trying," I counsel, but I've learned that astronomy is not for everyone. You wouldn't think the starry universe could possibly cause problems, yet you hear bizarre complaints. For example, PETA (People for the Ethical Treatment of Animals) wants astronomy's official institution, the IAU, to ban Sirius' nickname, the Dog Star. "We believe it's degrading to Dachshunds, Doberman Pinschers, and other dogs to have their name flippantly used like this," said PETA's Ricki Lake, a TV personality. PETA wants the sky's other starry animals gone, too. They think names like Leo the Lion and Taurus the Bull are forms of animal cruelty. I'm not making this up. But even people from our dimension have quit astronomy, sometimes for good reasons. Galileo was threatened with death. Brilliant *Celestial Handbook* author Robert Burnham, Jr., abandoned it when he went mad. Some Ph.D. holders leave astrophysics when they're offered only raccoon-level starting salaries.

Looking up at the universe is not built into every mammal. Wolves, yes. Cats, no. Some animals, such as dolphins, simply cannot focus their eyes on infinity. For our part, humans have an odd gender discrepancy. About nine times more males than females are into astronomy. Why is this? Anyone know? Whatever the reason, it starts young. You rarely see fourth-grade girls doodling rockets zooming past Saturn, the way we guys did as an alternative to whatever was happening on the chalkboard.

Up on most young boys' walls is a poster of the solar system. Sometimes it's part of a science phase that starts with dinosaurs, moves to astronomy, and then gets left behind. That period always includes having a telescope, and they've never been better than they are today.

But every telescope is a compromise. Research-grade instruments weigh a ton. Portable reflectors with short tubes demand collimation. Hassle-free refractors are economically unavailable in large apertures. You can't have it all. This bothers those who *do* want to have it all.

Looking up at the universe is not built into every mammal. Wolves, yes. Cats, no.

"Can't they make one telescope that does everything?" people ask. Of course not, just as sports cars aren't SUVs. Large can never be small. Lightweight can never mean huge-mirrored. A private observatory can solve it all, but how many of us have spare mountaintop acreage? Or vampire neighbors who keep all their lights off? Such compromises can weed out the pathologically fussy.

Ever hear of jailhouse astronomy? I taught astrophysics for 4 years at a maximum security prison for women. Those specially selected inmates were trying to get college degrees. Turns out, they all loved astronomy and stuck with it. Like the constellations, they had lots of time on their hands. Me, I enjoyed having a truly captive audience. Nobody could walk out of my classes, no matter how boring. But I couldn't get the warden to kill the lights. I actually asked, half in jest: "C'mon, just for 10 minutes." She stared at me in disbelief. However, these inmates showed why a lifelong passion for stargazing was so popular in bygone centuries: plenty of free time after nightfall.

"See that bright star? It's Jupiter!" is enough to hook any kid. But too often, no one starts them down that road. Most adults think the sky is hard, and ours is an age of easy. Star maps can look like hieroglyphs to beginners. They need a push.

The quick fix: Drag someone to a star party. It can change their life. Tell a single woman that lots of smart guys will congregate under the romantic Milky Way. In the dark, she'll never notice their clothes, which were stylish in 1972. Invite a bored friend to come "somewhere" that night, and when he experiences all those telescopes, he'll be amazed. He'll even overhear an intriguing language worthy of the ancient Mongols: "Slew to the Trifid and use the Plössl."

Stars galore, an occasional meteor, some knowledgeable amateurs explaining things? Bingo. The adventure begins. But will it last? That's why sharing astronomy can turn it into a clubby longtime hobby with regular meetings conducted in the local dialect. Yet as Earth's population grows, city dwellers face a diluted version of the universe. It makes those International Dark Sky evangelists chugalug Maalox by the liter. For carless urbanites, it's an April Fools' prank turned real. The problem is so awful, I've disguised it. To see this 21st-century "I give up" complaint, go back over this article and combine the first word of each paragraph.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Contact me about my strange universe by visiting **skymanbob.com.**

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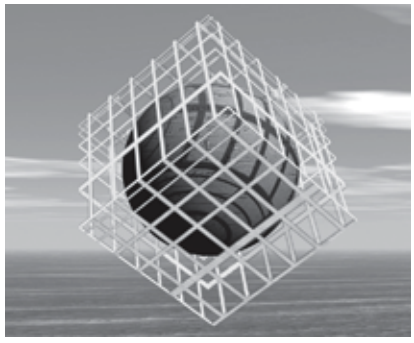

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Exoplanet extra! The Kepler space telescope's first discoveries, 5 new exoplanets, were announced January 4 at the American Astronomical Society meeting in Washington, D.C.

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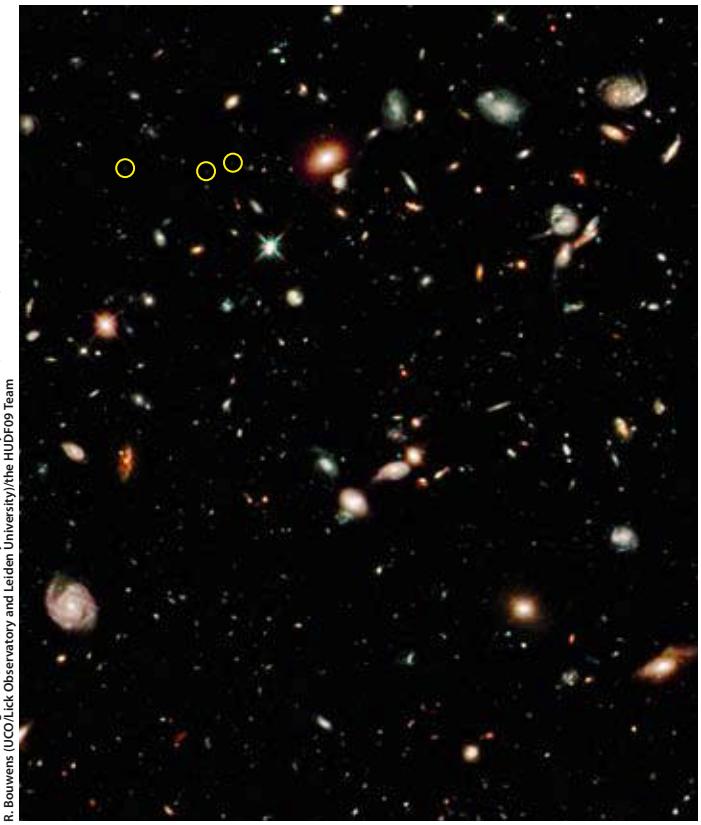


NASA/ESA/G. Illingworth (UCO/Lick Observatory and the University of California, Santa Cruz)/ R. Bouwens (UCO/Lick Observatory and Leiden University)/the HUDF09 Team

Infant galaxies. The upgraded Hubble Space Telescope stared at a patch of "empty" sky for 4 days and compiled this view of distant galaxies. Some of these star cities (circled) date to a time about 600 million light-years after the Big Bang, making them the most distant galaxies yet observed.

Hubble glimpses most-distant galaxies

In 2004, the Hubble Space Telescope took the deepest visible-light image of the cosmos. In the fall of 2009, using Hubble's newly installed Wide Field Camera 3 (WFC3), the telescope added to its accomplishments with the deepest image of the universe in near-infrared light. In the 2009 image, astronomers have identified galaxies at just 600 million light-years after the Big Bang, making them the earliest galaxies ever seen. NASA released the new Hubble Ultra Deep Field (HUDF09) December 8 and combined HUDF09 with the 2004 visible-light image for the American Astronomical Society meeting January 4.

In August, astronomers pointed Hubble toward the same spot as the 2004 HUDF. During a total of 4 days, the scope recorded the near-infrared radiation. Infrared radiation allows astronomers to see further back in time because the universe's expansion stretches the wavelengths of light from distant galaxies — for example, from visible to infrared. Hubble's new WFC3 can detect radiation ranging from ultraviolet to near infrared.

In addition to showcasing some of the first galaxies, the data in the HUDF09 paves the way for Hubble's successor, the James Webb Space Telescope. That mission, scheduled to launch in 2014, will examine the infrared cosmos. **— LIZ KRUESI**

Editor's note: *Be sure to check out next month's issue, in which Senior Editor Richard Talcott details the HUDF09 image.*

20 Magnetic fields may power gamma-ray bursts

21 Old Hubble data reveals smallest KBO

22 Iapetus' shading explained

23 Astronomers gain insight into rejuvenated stars

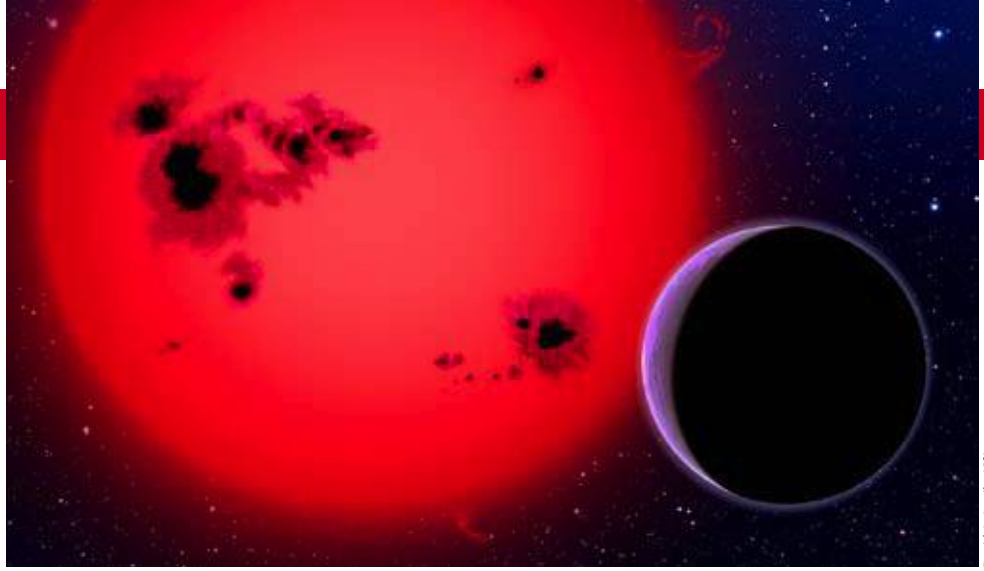
First super-Earths found with Sun-like stars

Astronomers have found for the first time Earth-sized exoplanets orbiting Sun-like stars using Hawaii's W. M. Keck Observatory. The two planets, called super-Earths because of their size between Earth's and Uranus', are some 5 and 7.5 times the mass of Earth, respectively.

"These detections indicate that low-mass planets are quite common around nearby stars," says Steven Vogt of the University of California, Santa Cruz. "The discovery of potentially habitable nearby worlds may be just a few years away." He and Paul Butler of the Carnegie Institution of Washington led the international team, whose two different papers appeared in the January 10 edition of *The Astrophysical Journal*.

The exoplanets orbit the stars 61 Virginis and HD 1461, and both seem to be too hot to support life or liquid water. **— BILL ANDREWS**

Solar-like system. This illustration shows four exoplanets in orbit around a distant Sun-like star. While such extrasolar planets have long been known to exist, astronomers recently detected super-Earths around such stars, a more significant — and difficult — achievement. NASA/JPL-Caltech



David A. Aguilar/CfA

Amateur exoplanet. **A fleet of ground-based telescopes popular with amateur astronomers detected exoplanet GJ 1214b, depicted here with the M dwarf star it orbits, around 40 light-years from Earth.**

Amateur telescopes detect new super-Earth

Astronomers found a "super-Earth" type exoplanet orbiting an M dwarf star about 40 light-years away, using the same off-the-shelf technology many amateurs use. A study in the December 17 *Nature* describes the planet, GJ 1214b, as about 6.5 times as massive as Earth, well within a super-Earth's defined limits of between 1 and 10 times Earth's mass.

The exoplanet's host star, GJ 1214, is so much dimmer and smaller than our Sun that GJ 1214b's surface temperature is only around 400° Fahrenheit (204° Celsius), even though it lies just 1.3 million miles (2.1 million kilometers) away. This makes it cooler than most other exoplanets, but still too warm, and with an atmosphere too thick, to consider habitable.

"This atmosphere is much thicker than that of the Earth, so the high pressure and absence of light would rule out life as we know it," says David Charbonneau, lead author of the paper.

These results were made possible because of the MEarth Project, which combines the data from eight identical 16-inch telescopes. They monitor M dwarfs with a charge-coupled device (CCD) chip, looking for changes in the stars' brightnesses. M dwarfs are ideal because a relatively small super-Earth would dim an M dwarf more noticeably than it would a much brighter Sun-like star.

"This means that anyone else with a similar telescope and a good CCD camera can detect [GJ 1214b], too," says Charbonneau. "Students around the world can now study this super-Earth!" — **B. A.**

New Hubble picture shows off star formation region

Caught in the act. **NASA's Hubble Space Telescope captured the most detailed view ever — about 100 light-years across — of the biggest stellar nursery in our part of the galaxy, a grouping of stars called R136 in the 30 Doradus Nebula in the Large Magellanic Cloud. The blue color represents the hottest and most massive stars, the green is the glow of oxygen, and the red comes from fluorescing hydrogen. — B. A.**

NASA/ESA/F. Paresce (INAF-IASF, Bologna, Italy)/R. O'Connell (University of Virginia, Charlottesville)/Wide Field Camera 3 Science Oversight Committee

QUICK TAKES

SPACE SIBLING
The Subaru Telescope observed for its first time a planet-like object orbiting a nearby Sun-like star. Results appeared online November 18 in *The Astrophysical Journal Letters*.

BINARY BIG DIPPER
The Big Dipper's star Alcor turns out to have a smaller red dwarf companion, according to a February 1 paper in the *The Astrophysical Journal*.

SURPRISE IN THE SKIES
A web site (www.uapreporting.org) launched December 16 provides a hub for sightings and reports of unexplained aerospace phenomena.

LOFAR, SO GOOD
Germany's Max Planck Institute for Radio Astronomy announced December 17 the completion of the first high-band, all-sky images from a complete LOFAR station.

LIQUIDS ON TITAN
NASA presented confirmation of liquid from a glint of sunlight on Titan, Saturn's largest moon, at the December 18 meeting of the American Geophysical Union.

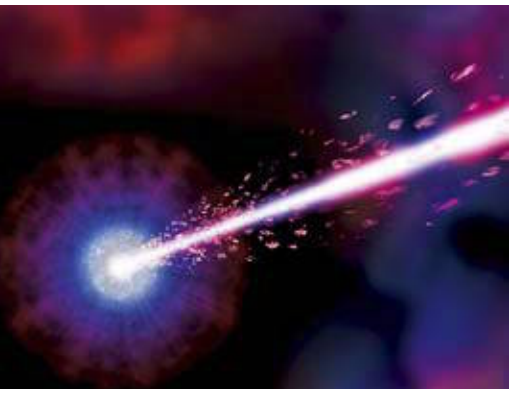
STARLIGHT VERY BRIGHT
NASA announced December 9 its Fermi Telescope had discovered the new brightest source in the gamma-ray sky, a galaxy 7.2 billion light-years away.

DUAL LUNAR PHOTO
Both martian moons, Phobos and Deimos, appear together on camera for the first time in a picture the European Space Agency released December 11.

SOFIA'S SO FINE
NASA's Stratospheric Observatory for Infrared Astronomy fully opened its telescope doors during a test flight December 18, an important milestone.

FOGGY NEWS ON TITAN
Caltech astronomers announced fog on Saturn's moon Titan at the American Geophysical Union meeting December 18, indicating an active hydrological cycle.

WEIGHTY MATTERS
On December 22, NASA announced the 28 teams of undergraduates it had chosen to test their science experiments during simulated weightlessness.



Polarized burst? **Magnetic fields may power gamma-ray bursts. Such blasts, like the one illustrated here, are the universe's most intense explosions.** *Astronomy*: Roen Kelly

Magnetic fields may power gamma-ray bursts

A team of U.K. astronomers announced it has found evidence that magnetic fields may fuel gamma-ray bursts (GRBs) — the most energetic explosions in the universe. Such a mechanism has been theorized, but this marks the first time magnetic fields have been observationally associated with a GRB. The team reported its finding in the December 10 *Nature*.

NASA's Swift satellite detected the GRB January 2, 2009, and immediately sent out a notification. The robotic Liverpool Telescope received the notice and moved to observe the burst. This telescope has a spinning disk of material called "Polaroid." "By observing how the brightness of the GRB varied as we spun the Polaroid, we could measure the magnetic field in the burst," says Iain Steele, director of the Liverpool Telescope and lead author of the *Nature* study.

Polarization — which can tell scientists about associated magnetic fields — is a difficult property to study, but it's an important one in astronomy. "These very interesting observations raise the possibility that gamma-ray bursts are not fireballs as usually presumed but are powered and collimated by an organized electromagnetic field," says Roger Blandford, director of the Kavli Institute of Particle Astrophysics and Cosmology at Stanford University, California, and who is not associated with the study. — **L. K.**

X-ray missions pass 10 years

In 2009, the world celebrated the 400th anniversary of Galileo's optical studies of the sky while two main X-ray satellites each celebrated a decade of operations. The NASA Chandra X-ray Observatory's anniversary was July 23, and the European Space Agency XMM-Newton satellite's was December 10.

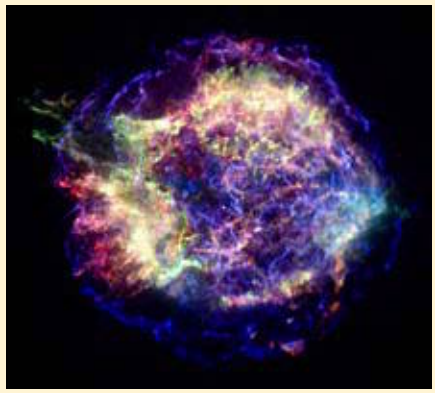
Because Earth's atmosphere blocks X-rays, telescopes used to study this radiation must be lofted above the atmosphere. Both Chandra and XMM-Newton follow elliptical orbits, which take them about one-third of the way to the Moon during apogee and below Earth's radiation belts at perigee. Chandra takes more than 64 hours to complete its orbit (82,640 miles [133,000 kilometers] at farthest approach and 9,940 miles [16,000 km] at closest). XMM-Newton takes 48 hours to complete its orbit (roughly 70,840 miles [114,000 km] at apogee and 4,350 miles [7,000 km] at perigee).

X-rays allow astronomers to view the universe in a different way from visible light. This high-energy radiation traces energetic events, such as supernovae, flares from black holes, and highly magnetized neutron stars. In the past 10 years, both satellites have contributed immensely to the field of X-ray astronomy.

Astronomers using XMM-Newton data have compiled the largest ever catalog of cosmic X-ray emitters. The European spacecraft has also probed the way black holes twist space-time around them. In this project, XMM-Newton studied X-rays emitted from iron atoms. And closer to home, scientists used the telescope to discover that Mars has a much larger atmosphere than expected, about 6 times Mars' radius.

Chandra has also contributed to the study of black holes. But more recently, the NASA mission provided independent confirmation that dark energy — the mysterious force causing the universe's expansion to accelerate — exists. Chandra has also given astronomers strong evidence that dark matter must exist. The telescope observed how hot gas had moved in the Bullet cluster — two galaxy clusters currently colliding and merging. While the hot gas slowed during the collision, dark matter hasn't. These are expected properties of such an event involving dark matter and gas.

Chandra's original mission of 5 years has already doubled. And it appears both Chandra and XMM-Newton have quite a few more years of discoveries left in them. — **L. K.**



NASA/CXC/MIT/UMass Amherst/M. D. Stage et al.

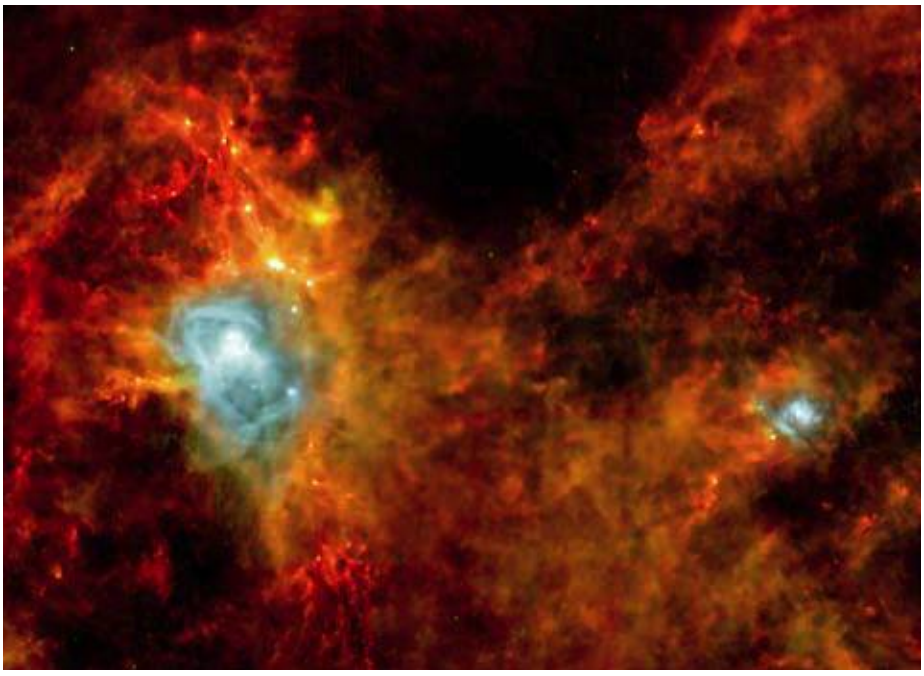
Supernova secrets. **The Chandra X-ray Observatory has observed supernova remnant Cassiopeia A for 10 years. In fact, it was the satellite's "first light" image. Over the decade, the observatory has seen the remnant grow.**

X-ray searcher. **XMM-Newton has actively studied black holes, supernovae, neutron stars, and other high-energy objects and events over the past decade. So far, more than 2,200 published papers have appeared regarding the telescope's data.**

ESA/D. Ducros

VISTA's view

The European Southern Observatory in Chile announced December 11 its new VISTA telescope began its work mapping the sky and releasing pictures.



Herschel peers into the Eagle's core

Veiled nursery. **The Herschel infrared space observatory peered through the dust shroud at the heart of Aquila the Eagle to capture a never-before-photographed stellar nursery. Astronomers estimate the region contains about 700 clumps of gas and dust on their way to becoming stars. The nursery lies 1,000 light-years away, and the view spans some 65 light-years. The European Space Agency released the image December 16. — L. K.** ESA and the SPIRE & PACS consortia/Ph. André (CEA Saclay) for the Gould's Belt Key Programme Consortia

Old Hubble data reveals smallest KBO

Everyone knows NASA's Hubble Space Telescope churns out some of the best, most beautiful images of the cosmos, but even its old archival footage can prove valuable. Hilke Schlichting of the California Institute of Technology and her collaborators pored over 12,000 hours of old observations to discover the smallest Kuiper Belt object (KBO) ever found with visible light.

The Kuiper Belt is a huge ring of icy and rocky debris encircling the solar system beyond Neptune's orbit. Naturally, that means the object Schlichting reported in the December 17 issue of *Nature* is tremendously distant — more than 4.2 billion miles (6.8 billion kilometers) away. Making the observation even more difficult, the object measures only 3,200 feet (975 meters) across. That's about 50 times smaller than the smallest KBO ever seen previously in visible light, which is some 30 miles (48 km) across.

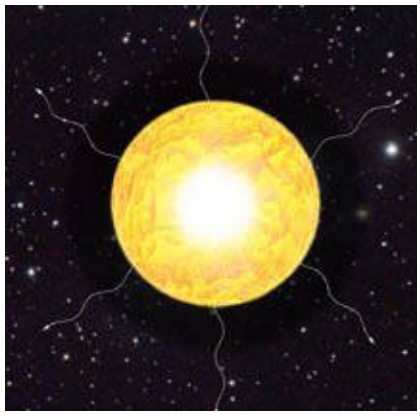
Actually, this latest KBO was too faint (only 35th magnitude) for Hubble to see it directly.

NASA/ESA/G. Bacon (STScI)

Sun block. **In this artist's impression, the recently discovered Kuiper Belt object blocks a distant star's light. It was through this interruption of light that the Hubble Space Telescope could detect the presence of such a small and distant object.**

Instead, Schlichting's team noticed a single 0.3-second-long event where something made a star temporarily dim. After analysis, they concluded a KBO with the properties noted above most likely blocked that star's light for the fraction of a second.

The team hopes to find more small KBOs like this one by scouring Hubble's data acquired since its launch in 1990. — **B. A.**



Berkeley Lab

Super-duper supernova. **SN 2007bi, illustrated just before the explosion, emitted unusual radiation that made it extraordinarily bright. It's the first observed example of the earliest kind of supernova.**

New kind of supernova provides link to the past

An unusually bright and long-lasting supernova detected in 2007 is the first known example of the kind of stars the universe initially produced. A paper in the December 3 issue of *Nature* describes this type of explosion as a pair-instability supernova. Named SN 2007bi, the supernova occurred in a nearby dwarf galaxy.

"It's significant that the first unambiguous example of a pair-instability supernova was found in a dwarf galaxy," says Peter Nugent of the international Nearby Supernova Factory, one of the authors of the paper. "These are incredibly small, very dim galaxies that contain few elements heavier than hydrogen and helium, so they are models of the early universe."

The analysis shows SN 2007bi's precursor star must have been enormous and made up of few elements besides hydrogen and helium. "But instead of turning into a black hole like many other heavyweight stars," says co-author Alex Filippenko of the University of California, Berkeley, "its core went through a nuclear runaway that blew it to shreds." Scientists had theorized about this type of supernova for decades, but this is the first observation.

"In the future," says Filippenko, "we might end up detecting the very first generation of stars, early in the history of the universe, through explosions such as that of SN 2007bi." — **B. A.**

New face for space

On December 18, NASA named Goddard official Laurie Leshin its new Deputy Associate Administrator for Exploration.

A 70-year stellar mystery deepens

After monitoring 58 Sun-like stars in the Large Magellanic Cloud for more than 2½ years, astronomers say they are even more unsure of why some late-stage stars exhibit odd periodic variations. These pulsations occur at the end of a Sun-like star's life (during the "red giant" stage), in about one-third of all such stars. The team's results appeared in two papers: the December 10 issue of *The Astrophysical Journal* and the November issue of the *Monthly Notices of the Royal Astronomical Society*.

The team used the European Southern Observatory's Very Large Telescope in conjunction with telescopes in Chile and Australia to monitor the red giant stars. Astronomers expect these stars to undergo variations in their luminosities over timescales of a few years. "However, one-third of these stars show an unexplained additional periodic variation, on even longer timescales — up to 5 years," says team leader Christine Nicholls of the Mount Stromlo Observatory in Australia.

The observations don't correlate with any theorized model of the red giants' pulsation behavior. Astronomers have tried to understand this mystery since the 1930s, and it looks as though they're no closer to determining the cause. — **L. K.**

NASA/JPL/Space Science Institute

Galactic mystery. **Saturn's moon Iapetus' trailing side, shown in this Cassini-Huygens image, is about 10 times brighter than its leading side.**

Iapetus' shading explained

New models and analysis based on Cassini-Huygens data might solve one of the most striking mysteries of the solar system. Ever since Giovanni Cassini discovered the saturnian moon Iapetus in 1671, astronomers have wondered why one side is so much brighter than the other. Specifically, the moon's leading side, which faces forward in its orbit around Saturn, is 10 times darker than the opposite, trailing, hemisphere.

In two papers published online December 10 in *Science*, Tilmann Denk and John Spencer argue that a prominent theory, that dust in the moon's path coats the leading side, can't be the whole answer. "It is impossible that the very complicated and sharp boundary between the dark and the bright regions is formed by simple infall of material," Denk says. "We had to find another mechanism."

That other mechanism is the migration of ice as it evaporates from the darker, warmer areas facing the Sun to settle on the cooler, brighter areas at the poles. Iapetus' small size, just 900 miles (1,500 kilometers) across, means it has comparatively little gravity, which lets the ice move easily across the surface. The process serves to exaggerate the differences, making the cold areas cooler (and brighter) and the warm areas warmer (and darker). — **B. A.**

BRIEFCASE

Supernova imprints reveal type

The shapes of leftover remnants following stellar explosions (called supernovae) may reveal details of the initial explosions, say astronomers. A team led by scientists from the University of California at Santa Cruz studied 17 supernova remnants and found that type Ia supernovae tend to produce symmetrical remnants while "core-collapse" supernovae have asymmetrical remnants. The study appeared in *The Astrophysical Journal Letters* November 20. — L. K.

WISE launches

NASA's Wide-field Infrared Survey Explorer (WISE) launched successfully December 14 and released its first image January 6. The mission will observe the entire sky in infrared light over 10 months. Along the way it will see the glow from "hundreds of thousands of asteroids and hundreds of millions of stars and galaxies," says Principal Investigator Ned Wright. — L. K.

Curtains light up

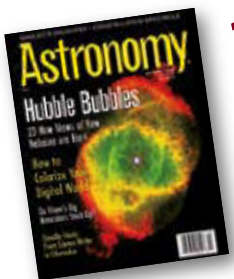
Scientists announced December 17 at the American Geophysical Union meeting that sometimes auroral curtains collide and then produce outbursts of light. Researchers using NASA's THEMIS spacecraft, in addition to ground-based cameras and radar, made the discovery. This detection can help scientists learn more about Earth's "plasma tail," a sheet of charged particles pointing away from the Sun. — L. K.

25 years ago in *Astronomy*

April 1985

In the April 1985 issue of *Astronomy*, science writer Nigel Henbest discussed Britain's improving astronomical prospects in "British Astronomy Reaches New Heights on La Palma." Tired of having to practice "invisible astronomy" in the radio and X-ray spectra because of England's notoriously poor weather, British astronomers decided to place optical telescopes on La Palma of the Canary Islands, "among the best sites — possibly the best site — in the world for the optical observatory."

Henbest suggested the progressive move is "a result of the Government's 'positive discrimination' in funding astronomy." Unfortunately, in December 2009 Britain's Science and Technology Facilities Council cut all funding for ground-based optical observatories in the Northern Hemisphere, including, among other programs, La Palma.



April 2000

10 years ago in *Astronomy*

The April 2000 issue of *Astronomy* published an excerpt of science writer Dava Sobel's most recent novel at the time, *Galileo's Daughter*. The author of *Longitude* and later *The Planets*, Sobel sought to humanize a historical personage most known for his scientific work. "Forgotten aspects of Galileo's life … are made clearer to us in the letters written to him by his daughter, Sister (Suor) Maria Celeste."

The letters discuss not the heavens or science, but everyday life. "The lemons that hung in the garden all dropped, [and] the last few remaining ones were sold," Sister Maria Celeste informs Galileo at one point. The passages, combined with Sobel's context and insight, serve to paint Galileo in strikingly human tones. — **B. A.**

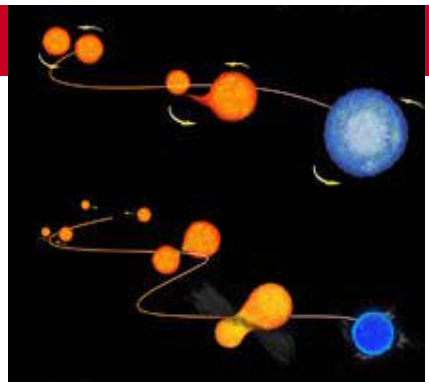
NASA/ESA/L. Ricci (ESO)

A plethora of proplyds

Forming disks. **Astronomers with the Hubble Space Telescope released 30 images of protoplanetary systems in the Orion Nebula December 14. These "proplyds" are part of 42 that Hubble has observed during the telescope's longest project dedicated to star- and planet-formation.**

Two kinds of proplyds dot the nebula. One type appears to glow because the disks are close enough to the nebula's primary star that the star heats the disks' gas. The other proplyds are too far from the star to glow, and thus appear as dark silhouettes against the nebula background. — L. K.

Astronomers gain insight into rejuvenated stars



Rejuvenated stars. **Blue stragglers are hot blue stars that appear to have been "reborn" somehow. Two teams of astronomers have found evidence supporting the two formation theories: "vampirism" (shown at top) and head-on collisions (seen at bottom).** NASA/ESA

For some 50 years, astronomers have observed occasional massive blue stars in old globular star clusters. Blue stars are hotter and burn out faster than red stars, so one wouldn't expect blue ones to exist in globular clusters, which are about 10 to 13 billion years old. For decades, astronomers have theorized two ways that such stars — called "blue stragglers" — can form. Now, two separate groups of scientists have found evidence to support those theories. The findings appeared in the December 24 issue of *Nature*.

In one theory, called "vampirism," a close binary star system evolves into a blue straggler. After the more massive star's outer layers puff out — making the star a red giant — the second star pulls hydrogen from the red giant. This leaves behind a small core and a massive companion star that can burn the additional hydrogen, heating up and appearing bluer.

In the second theory, two stars collide and merge. Because a globular cluster's core is packed with stars, stellar collisions can happen often. Such a violent event would disrupt stellar material, mixing hydrogen deeper into the star. This allows the newly created star to burn brighter and hotter as a blue star.

Francesco Ferraro of the University of Bologna in Italy and colleagues used the Hubble Space Telescope to study blue stragglers in M30. They found evidence for both methods. "Our observations demonstrate that blue stragglers formed by collisions have slightly different properties from those formed by vampirism," says team member Giacomo Beccari.

Robert Mathieu and Aaron Geller, both of the University of Wisconsin-Madison, studied blue stragglers in cluster NGC 188. They found that most of those stars originate in binary systems, and, as they wrote, "that the several formation processes [vampirism and collisions] operate simultaneously." — **L. K.**

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How many civilizations

Fifty years after Frank Drake quantified life in our galaxy, here's where we stand. **by Steve Nadis**

The search for intelligent life on other worlds began nearly 50 years ago. This quest hasn't succeeded yet, but the "Drake Equation" can help astronomers narrow down how many planets in the galaxy may harbor communicating life.

Frank Drake (then an astronomer at Cornell University) began the search in 1960 with an 85-foot radio telescope at the National Radio Astronomy Observatory in Green Bank, West Virginia. He looked for artificial radio signals emanating from two nearby stars, Tau (τ) Ceti and Epsilon (ε) Eridani. This observing run, dubbed "Project Ozma," lasted just 2 months and turned up empty-handed. But it launched the search for extraterrestrial intelligence (SETI). In his brief, pioneering effort, Drake showed that one could use the technology available then to look — or "listen" — across the distances between stars for signs of alien civilizations.

To put SETI on a firmer scientific footing, the National Academy of Sciences asked Drake to convene a small meeting to assess the odds of detecting intelligent life beyond Earth. Drake served as the entire scientific organizing committee of the 1961 meeting at Green Bank. He invited everyone in the world he knew who was interested in the subject — "all 12 of them," he recalls. "And all 12 of them showed up."

To serve as an agenda, Drake devised an equation for estimating how many communicating civilizations might lurk in the galaxy. That number, N according to Drake's formulation, is simply the product of seven other numbers. So if we could nail down those seven terms, we'd have an answer to the age-old question: "Is anybody out there?"

"Everyone has long forgotten about that Green Bank meeting," says Drake, who is the only attendee still alive. "But for some reason they haven't forgotten about this equation."

The "Drake Equation," as it's now called, has turned out to be a very long-lived, as well as useful, tool, notes Jill Tarter, Drake's colleague at the SETI Institute. So what is the equation good for? And are we any closer to "solving" it today than we were when Drake drafted his meeting agenda half a century ago? Here's the Drake Equation: $N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$.

$$N = R^* f_p n_e f_l f_i f_c L$$

lurk in the cosmos?

Advanced civilizations likely exist elsewhere in the Milky Way — we just haven't found them yet. According to modern estimates of values in the Drake Equation, astronomers may have to search some 20 million stars before finding one that supports a communicating civilization. Lynette Cook for *Astronomy*

Hubble Image: NASA/ESA/N. Smith (University of California, Berkeley)/The Hubble Heritage Team (STScI/AURA); CTIO Image: N. Smith (University of California, Berkeley)/NOAO/AURA/NSF

Star-forming regions, like those found in the Carina Nebula, dot our galaxy. Such regions contribute to the creation of, on average, about 10 stars a year. Here ultraviolet radiation from hot newborn stars erodes nearby gas.

$$N = R^* f_p n_e f_l f_i f_c L$$

- N is the number of communicative civilizations in the Milky Way.
- R^* is the average rate at which suitable stars — those that could potentially harbor life — are born each year in our galaxy.
- f_p is the fraction of those stars that have planets.
- n_e is the number of planets per star that are, in principle, suitable for life.
- f_l is the fraction of habitable planets on which life actually originates.
- f_i is the fraction of life-bearing planets where intelligent life emerges.
- f_c is the fraction of those planets on which technology capable of producing detectable signals develops.
- L is the average lifetime of a communicating civilization.

Every factor in the equation is equally important, Drake says. Yet the terms become progressively more uncertain as one moves from the left to the right, which is why some people have called the Drake Equation "a shorthand for our ignorance." Drake, however, sees it in a more positive light, calling it "a way of organizing the search that actually gives us some insights into what we need to know."

Steve Nadis *is an* Astronomy *contributing editor.*

He's not alone in that assessment. "I'm often at meetings about life in the universe that use the seven factors of the Drake Equation to organize the whole conference," recalls astronomer Dan Werthimer of the University of California at Berkeley. "It's a way of compartmentalizing the problem." Take a big, almost unapproachable, problem and break it into seven smaller questions that we might make some headway on.

And scientists are making headway, Werthimer affirms. "We're slowly whittling away at the Drake Equation. It used to be we had no idea what any of the factors were except the first one." Now researchers are making advances on multiple fronts — a testament to achievements in astronomy, planetary science, origin of life research, and investigations into the evolution of intelligence.

Because the whole point of the Drake Equation is to reduce one huge, multifaceted question into seven distinct ones, perhaps the best way to evaluate progress toward "solving" the equation is to look at each of these factors separately before putting them together.

R^* the average rate at which suitable stars are born each year in our galaxy

In 1961, Drake assumed that, on average, 10 stars form in the galaxy each year, which still seems like a reasonable guess. If you start with some 200 billion stars in the Milky Way and divide that number by the galaxy's lifetime (approximately 10 billion years), you get about 20 stars per year.

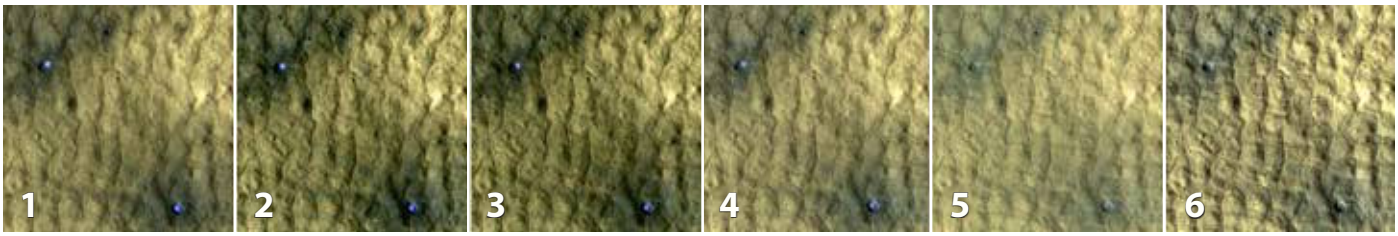
But the really big stars burn out fast — in just millions of years — which would probably not allow time for intelligent species to evolve. If we throw out the fast-burning stars, we still have about 19 stars a year. And of those 19, only about 4 are like the Sun. The other 15 are smaller stars, known as M dwarfs, whose suitability for intelligent life is open to debate.

Previous theories held that M dwarfs would be inhospitable to life. For a small, dim M star to warm a planet, the planet would be so close it would become "tidally locked" — always facing the same direction, just as the Moon is to Earth. The atmosphere on the cold side would freeze and collapse, thereby crushing any hopes for a viable biosphere.

But more recent models suggest "tidal locking is not a showstopper," says Berkeley astronomer Lucianne Walkowicz. "These models show that it's possible to have an atmosphere that circulates heat around," thereby avoiding the predicted collapse. M dwarfs are so numerous (constituting 70 percent of the stars in the galaxy) "that even if some are not suitable, there are many others that potentially might be," adds Walkowicz. So depending on what we conclude about M dwarfs, Drake explains, R^* could be 4 to 19, with 10 somewhere in the middle.

f_p the fraction of suitable stars that have planets

At Green Bank, Drake originally picked a value of 0.5, meaning that out of all the stars that form, half will have planets. But he now believes that number could be higher. Indeed, Berkeley astronomer Geoff Marcy estimates that about 90 percent of all stars have planets. When Drake



NASA/JPL-Caltech/University of Arizona

Two small, fresh craters on Mars' surface start out with water ice (the bluish material in the first images), but after 15 weeks the ice has sublimated. Scientists think meteorite impacts created the fresh 13-foot-wide (4 meters) craters. The images span September 12, 2008, to December 25, 2008.

first came up with his famous equation, no one could say for sure that any stars other than the Sun had planets. Since that time, astronomers have discovered more than 400 extrasolar planets, with Marcy and his associates responsible for about 170 of those worlds.

Astronomers know there are many more undiscovered planets — possibly hundreds of billions in this galaxy alone. They've missed many because techniques available until recently could not reveal slow-moving planets or those much smaller than Neptune. But new technology should give them a much better idea of the fraction of stars with planets. Most promising at the moment is the Kepler mission, which launched in March 2009 to find "terrestrial," or rocky, planets like Earth. Marcy calls Kepler "the most fantastic mission of the upcoming decade."

Kepler's 1-meter telescope is taking pictures of the constellation Cygnus, capturing light from 100,000 stars. When a planet crosses in front of its star, the detected light will dim. If Kepler detects a star's dimming by just 20 parts in a million, says Marcy, "earthlike planets will stick out like a sore thumb."

Armed with data from Kepler and other ventures, researchers will soon know more about the prevalence of earthlike planets in the universe. "That's the primary motivation of my work," says Marcy, "and it's also one of the key terms of the Drake Equation."

n_e the number of planets per star that are, in principle, suitable for life

Drake guessed in 1961 that among stars with planetary systems, two planets on average can sustain life. Based on what we knew at the time, of course, n_e for our solar system was one. Earth was the only planet we knew that met the conditions deemed necessary for life, such as liquid water on the surface.

Over the years, there's been a gradual realization that the traditional notion of a "habitable zone" — just the right distance from a star for liquid surface water to exist — may be too restrictive. Life is more resilient than we once believed. On Earth, for example, scientists recently came across hardy microbes called "extremophiles" that can tolerate water of extreme acidity and temperatures well above the boiling point, as well as survive in solid ice.

Researchers now believe that n_e for our solar system is at least four, according to Chris McKay of NASA's Ames Research Center. In addition to Earth, planetary scientists have found evidence of liquid water on Mars, Jupiter's moon Europa, and Saturn's moon Enceladus. "The nice thing about n_e," says McKay, "is that as we learn more, it can only get bigger." We've now seen that conditions for life might exist on planets or satellites far from the Sun and outside the normal habitable zone because they rely on other energy sources — geothermal, tidal, or radioactive — to keep some water in liquid form.

f_l the fraction of habitable planets on which life actually originates

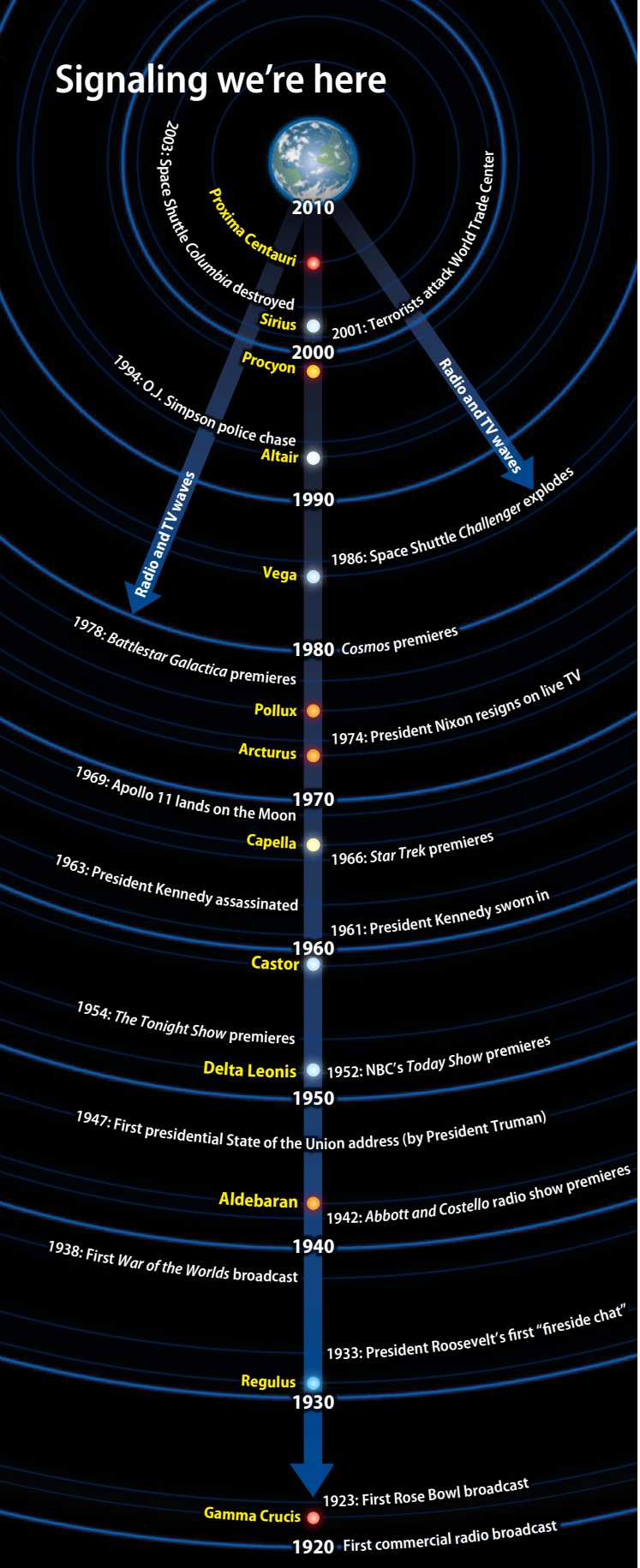
In 1961, Drake assumed that f_l is close to one, meaning that life should develop on planets that have the right conditions. Evidence acquired in the intervening years only solidifies that view. We've learned that water is almost ubiquitous throughout the galaxy. And we've seen that the other basic ingredients of organic chemistry — including carbon and hydrogen — are widespread within the galactic clouds out of which stars form.

In 2009, University of Manchester chemist John Sutherland and colleagues showed how those ingredients may have given rise to life on Earth — a process that would apply wherever similar conditions are found, Sutherland says. "Since the rules are the same everywhere, chemistry should give you the same product."

Researchers now believe that life as we know it is based on RNA — a close cousin to DNA but simpler to make. Sutherland and his collaborators showed how common ingredients — heated and then held at roughly room temperature and in the presence of ultraviolet radiation (or sunlight) — can spontaneously assemble themselves to form nucleotides, which are the building blocks of RNA.

"If you find the same conditions around another star, it will happen," says Sutherland. "Spontaneous assembly is not magic. Chemistry is simply a description of how molecules behave, and the molecules in this case are not

NASA's Kepler mission looks for planets large and small around stellar habitable zones. The spacecraft has the sensitivity to detect an Earth-sized world orbiting another star. NASA



Human beings have been spewing communicative radiation into space for only about 100 years. This diagram shows where various radio and television programs have reached by now. So far, only technological societies near Earth — if they exist — would even know we are here. *Astronomy*: Roen Kelly

doing anything 'smart,' even while combining to create something more complex."

During the next 20 years, notes McKay, the challenge of planetary science in our solar system is to see if the number of inhabited planets is greater than one, just as the past 20 years has seen the number of habitable planets move from one to four. NASA's proposed Terrestrial Planet Finder — as well as the European Space Agency's Darwin mission — could examine earthlike planets around other stars and take the spectra of their atmospheres to see if there's oxygen, signaling the presence of photosynthesis or other hints of life.

f_i the fraction of life-bearing planets where intelligent life emerges

Drake assumed in 1961 that f_i is close to one, meaning that some sort of intelligence likely will evolve on planets where life appears. Recent findings support that claim. Lori Marino (Emory University), Daniel McShea (Duke), and Mark Uhen (Smithsonian Institution) looked at fossilized craniums of dolphins and toothed whales from a 50-million-year period to see if there is a noticeable increase in brain size and, by inference, intelligence.

Rather than seeing an inexorable drive toward increased intelligence, they found a more general "fanning out" process: The intelligence of some animal groups increased while others declined. Although the average intelligence may not have increased, the researchers did observe steady gains at the upper end of the spectrum. They see this pattern as more or less necessary for any biology that favors diversity, assuming there is no limit or "upper bound" on intelligence.

Even single-celled organisms like amoebas exhibit signs of intelligence, says Marino, because they can respond to the environment and make adjustments. Every unicellular organism we know of has a membrane, and membranes are precursors to neurons or nerve cells, she says. Once we have multicellular life, the establishment of a nervous system is virtually inevitable.

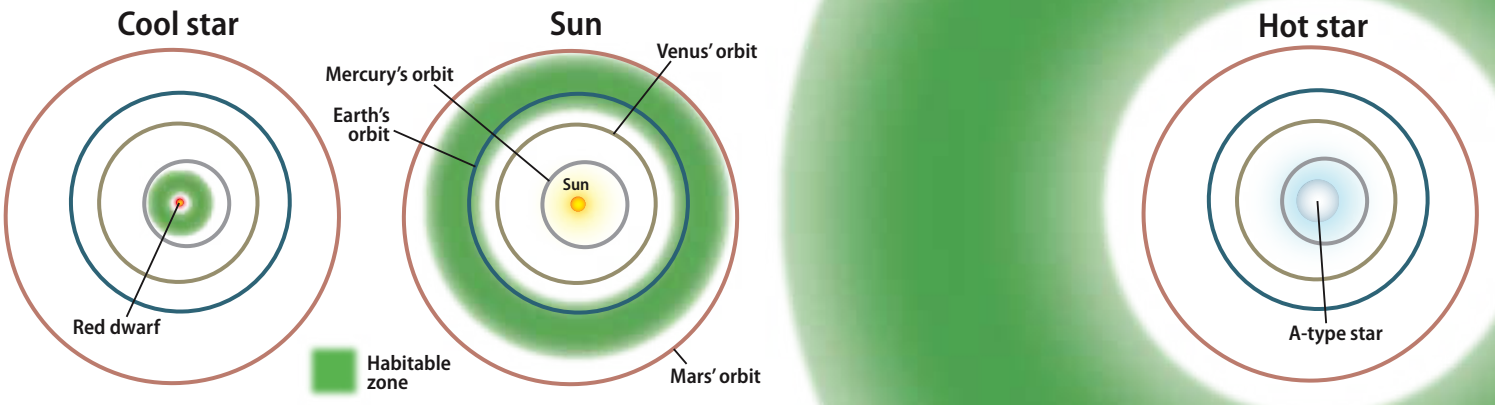
"All it takes is an environment that puts pressure on an organism, and an organism that can adapt to that pressure, and the development of intelligence becomes almost certain," argues Marino, whose research places f_i close to one, just as Drake had intuited.

f_c the fraction of those planets on which technology capable of producing detectable signals develops

Drake's original estimate for f_c was 0.1, meaning that communicative civilizations will emerge on 10 percent of the planets with intelligent life. The only real evidence we have is on Earth, but Drake finds that compelling. "Technology developed independently in so many different places here," he says. "Once you have enough intelligence in a creature whose anatomy allows the use of tools, you should get technology."

"It seems obvious that if a species has the brainpower for speech, along with the sort of appendages that can manipulate a pair of pliers, it will eventually blunder into science, technology, and radio," argues SETI Institute astronomer Seth Shostak.

Comparing different habitable zones



A star's habitable zone (HZ) depends on the size and temperature of the star. If it's a hot sun (such as an A-type star), its wide HZ will sit farther out. If the star is cooler (such as an M dwarf), its HZ will be thinner and sit closer to the star. *Astronomy*: Roen Kelly

Whether it was inevitable or not, James Clerk Maxwell worked out the basics of electricity and magnetism around 1860, and the first radio devices began appearing a couple of decades later.

Drake, like Shostak, suspects that other intelligent civilizations are likely to follow a similar pattern. Drake now believes f_c may be closer to 100 percent.

L the average lifetime of a communicating civilization

Just because a civilization is detectable doesn't mean it will always be detectable. This brings us to *L*, the most uncertain term of the Drake Equation. As earthling society has been detectable in the radio band for only about a century (see "Signaling we're here" on page 28), no one really knows how big *L* can get. There are two issues. The first is how long technological civilizations — endowed with the ability to blow themselves up — survive. The lower bound could be just a few decades while the upper end could conceivably be billions of years depending on the lifetime of the parent star.

A separate question concerns the mode of communications, as we're currently moving toward quieter radio and TV technologies. Old-fashioned TV transmitters broadcasted at a million watts, says Drake, "and most of that went straight into space." Satellite dish network systems transmit at just 20 watts, and only about 2 watts go into space, he adds. If this continues, we might eventually become invisible.

The question then is, "What technology comes next?" For example, solar power satellites — which place huge solar energy collectors in orbit and beam that energy to Earth in the form of microwaves — may transmit a billion watts, reflecting 10 million watts back into space, even with efficient antennas. "If that's the wave of the future," says Drake, "civilizations may stay visible for a very long time."

He points out that *L* is an average and so is dominated by civilizations with long lifetimes. Suppose there are 100 civilizations, 99 of which are detectable for just 100 years. But one of them is detectable for a billion years because it has gotten past the nuclear holocaust threat and is intentionally sending out a beacon to other, less-advanced galaxies. This would raise the average value of *L*, to 10 million in this case.

N the number of communicative civilizations in the Milky Way

How many civilizations might we hear from if we determine where to tune in? That's what *N* is for, although many astronomers, such as Cole Miller at the University of Maryland College Park, believe there's no need for a value for *N*. "The Drake Equation's biggest contribution is in framing the discussion rather than providing an absolute answer," Miller says. "You can get the conclusions you want while appearing reasonable and conservative throughout," Miller explains. "If you think many civilizations exist, you can use the Drake Equation to demonstrate this. If you think we are the only ones, you can get the equation to say that as well."

Although Drake readily acknowledges the uncertainties in his equation, he is encouraged by the fact that observations have bolstered many of the assumptions he made in 1961. If anything, says Drake, "the numbers we've been plugging in are too small."

His best guesses almost 50 years ago were $R^*=10$, $f_p=0.5$, $n_e=2$, $f_l=1$, $f_i=1$, $f_c=0.1$, $L=10{,}000$. Plugging in those values, $N = 10 \times 0.5 \times 2 \times 1 \times 1 \times 0.1 \times 10{,}000 = 10{,}000$. If that's right and there are 10,000 communicative civilizations in our galaxy, the search still will be challenging, because we may have to look at 20 million stars before finding anything.

"Any science where the uncertainties are great is an experimental science rather than a theoretical one," adds Jill Tarter. And that's probably how it ought to be, given that the "S" in SETI stands for "search."

Learn more about the SETI Institute and its radio observations at www.Astronomy.com/toc.

Secrets of

Geysers erupt from the surface of a Kuiper Belt object, while a crescent moon circles overhead and the distant Sun glows weakly. Lynette Cook for *Astronomy*

the Kuiper Belt

The frigid edge of our planetary zone has launched a white-hot revolution in understanding the solar system's origin and evolution. **by S. Alan Stern**

On the afternoon of February 18, 1930, 24-year-old Clyde Tombaugh made the discovery of a lifetime. The Lowell Observatory astronomer was comparing two photographic plates taken the previous month when he spied a tiny speck of light that appeared in a slightly different position relative to the fixed stars of Gemini. Within months, astronomers named the object "Pluto," and the solar system gained its first planet beyond Neptune.

It took several decades before astronomers found another such object. In 1992, University of Hawaii researchers Dave Jewitt and Jane Luu spotted a large object that circles the Sun entirely beyond the orbit of Neptune. The discovery of Kuiper Belt object 1992 QB_1 convinced astronomers that a vast belt, or disk, of such objects surrounds our solar system. These ancient bodies represent relics of the planet formation era.

Yes, there had been hints of this belt before. In the 1930s, '40s, and '50s, a few planetary scientists — Frederick Leonard, Kenneth Edgeworth, and, most famously, Gerard Kuiper — speculated that such an ensemble of far-flung bodies might exist in the deep outer solar system.

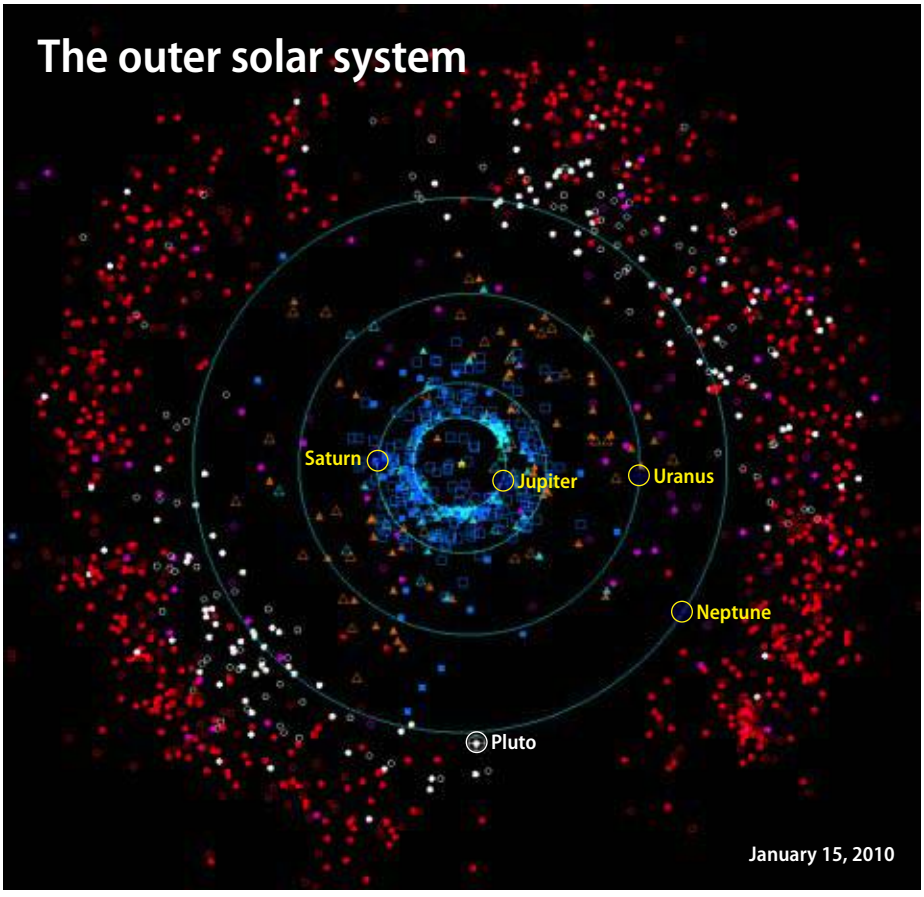
Then, in 1978, Charles Kowal of the University of Arizona discovered an icy body later named Chiron that orbits the Sun largely between the orbits of Saturn and Uranus. This 110-mile-wide (180 kilometers) object follows a path that cannot be stable for millions of years, however, so it must have originated farther out. But even the discovery of Chiron, which astronomers now recognize as an escapee from the Kuiper Belt, didn't make the case for this belt compelling.

That changed in the late 1980s, when cometary dynamicists began to pile up convincing evidence. Their orbital integrations showed that the even farther-flung Oort Cloud of comets can't supply the preponderance of comets orbiting in the disk of the planets. As a result, a consensus started to form among planetary scientists that the so-called Kuiper Belt just might exist after all. Soon, increasingly sophisticated dynamical models confirmed this result, indicating that a distant reservoir of comets and possibly larger bodies orbits beyond Neptune.

Observers turned their telescopes and CCD cameras skyward to find those bodies. Jewitt and Luu's discovery of 1992 QB_1 came after several years of difficult searches by various teams straining to find these proverbial needles in a haystack. Even the brightest glow at 24th or 25th magnitude — millions of times fainter than the dimmest objects visible to the naked eye — and barely move against the stars.

Within a year of QB_1's discovery, astronomers found four more Kuiper Belt objects (KBOs). A year later, the tally was 10, and by the 10th anniversary of QB_1's discovery, the count of KBOs was nearing 1,000. But even more amazingly, the searches that nabbed all of these bodies had scanned barely 1 percent of the more than 15,000 square degrees of sky along the plane of our solar system, called the ecliptic.

S. Alan Stern *is a planetary scientist and a former NASA Associate Administrator who was responsible for all Earth and space science missions. He is the principal investigator of NASA's New Horizons mission, which will visit Pluto and the Kuiper Belt later this decade.*



Gareth Williams/Minor Planet Center

The Kuiper Belt is a vast disk containing thousands of objects. In this illustration, red shows classical KBOs; white denotes KBOs in 2:3 resonance with Neptune; and magenta reveals scattered-disk objects.

Planetary astronomers soon realized the huge tally of discoveries in the tiny fraction of the sky searched meant that they had stumbled upon a vast population of previously unknown bodies. The Kuiper Belt stretches more than 6,500 square astronomical units (or AU; 1 AU is the average distance between the Sun and Earth, or about 93 million miles [150 million km]). The belt rings the Sun in a broad torus that stretches out to at least 55 AU.

Rewriting the textbooks

The discovery of the Kuiper Belt redrew our map of the solar system. After all, the Kuiper Belt is the largest structure in the entire planetary system. It dwarfs the asteroid belt in scale, in mass, and in sheer numbers, and stretches more than twice the breadth of the giant planet region. The discovery proved no less dramatic than when Earth's Pacific Ocean was discovered and all the maps had to be completely redrawn.

Equally amazing was the realization that the Kuiper Belt contains so many large bodies. Astronomers estimate that QB_1 is about 60 miles (100 km) across, so it likely has about 30,000 times the mass of a typical comet. But observers soon discovered bodies two, three, and eventually more than 10 times as wide and a thousand times as massive as QB_1. Scientists came to realize that the Kuiper Belt retains both the building blocks of planets and also dwarf planets themselves — bodies hundreds and even thousands of miles across.

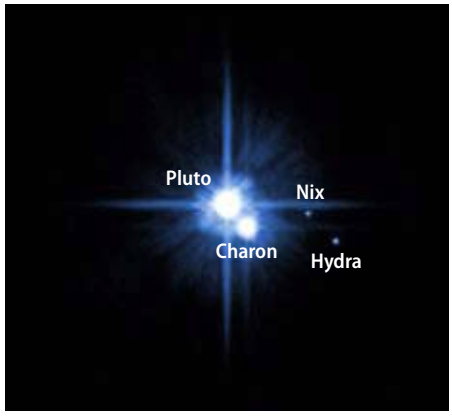
The discovery of the Kuiper Belt revealed Pluto's context for the first time. Far from being a lone misfit dwarf world on an odd orbit, Pluto turns out to be the first object discovered among a vast population of small planets that litter the deep outer solar system.

These twin revelations — the discovery of our planetary system's largest structure and the realization that the early solar system created so many dwarf planets — fundamentally changed astronomers' perceptions of our neighborhood. You'd have to go back to the discoveries of Uranus and Neptune in earlier centuries for an equivalent breakthrough in understanding.

Scientists knew all this by the time the Kuiper Belt's discovery was only a decade old. But we didn't know then that the Kuiper Belt held even more surprises, each more mind-blowing than its predecessor.

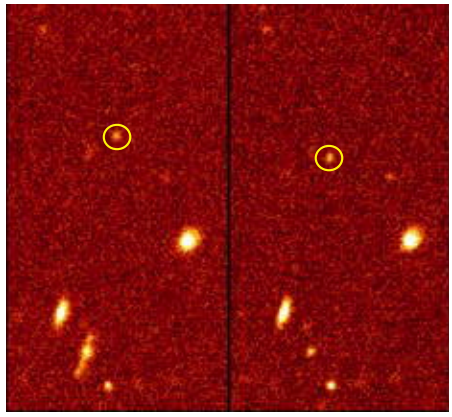
The tip of the iceberg

First, scientists who model planet formation learned that the large objects in the Kuiper Belt could not have been created in the belt as we know it today. Several scientists and I were among those who found that the current Kuiper Belt is too dilute — the material spreads too thinly to form the massive bodies located there. (My colleagues included Josh Colwell of the University of Central Florida in Orlando; Don Davis of the Planetary Science Institute in Tucson, Arizona; and the late Paolo Farinella of the universities of Trieste and Pisa

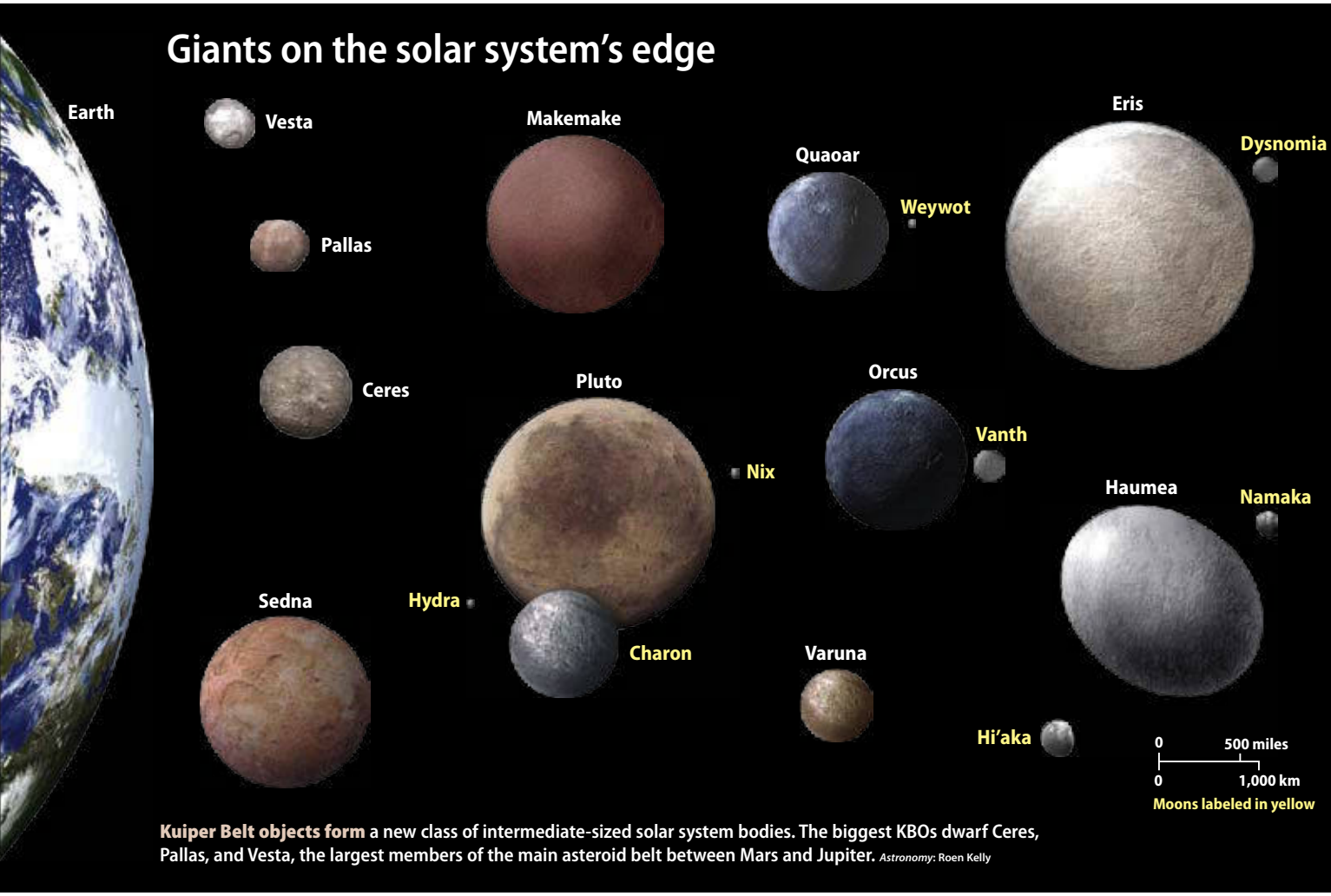


Hal Weaver (JHUAPL)/Alan Stern (SwRI)/NASA/ESA

The first Kuiper Belt object astronomers discovered was Pluto, although no one knew it at the time. We now know the Pluto system contains one large moon (Charon) and at least two smaller ones (Nix and Hydra).



This unassuming dot turned out to be 1992 QB_1, the first Kuiper Belt object scientists recognized as one. This dim point of light (circled) moved slightly between these two photographic exposures. David Jewitt (University of Hawaii)



Kuiper Belt objects form a new class of intermediate-sized solar system bodies. The biggest KBOs dwarf Ceres, Pallas, and Vesta, the largest members of the main asteroid belt between Mars and Jupiter. *Astronomy*: Roen Kelly

in Italy.) Instead, numerical models reveal that something like 10 to perhaps as much as 50 Earth masses of material must have once been present to grow into the objects we find today. This totals several hundred times the current Kuiper Belt's mass.

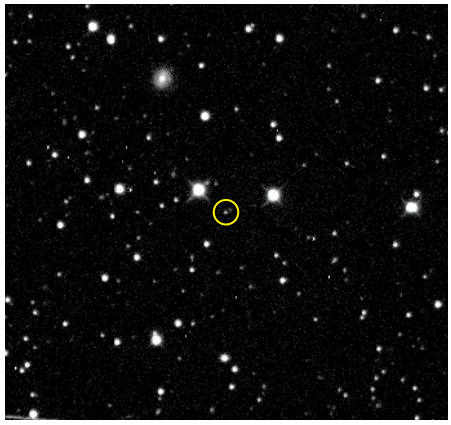
Studies of KBO orbits clearly show that most of the objects are on paths far too eccentric and inclined to the plane of the planets to have accreted at all. To grow large bodies, like those in the Kuiper Belt and the planets, the orbits of the smaller building blocks must have relatively low eccentricities and inclinations. Only then will the building blocks collide gently and promote the early accretion.

So, just as the existence of the large bodies tells us that the Kuiper Belt once had much more mass than it does today, the orbital distribution of these bodies indicates that something has greatly disturbed the dynamics of the Kuiper Belt — and thus the orbits of the bodies in it.

The revelation that the present-day Kuiper Belt is a far different place from the ancient Kuiper Belt was another shocker because it implies that the outer solar system experienced a dramatic evolution. It also raised a new question: Where has all the "missing mass" gone?

Clues to this and even greater insights came from further studies of KBO orbits. The first clue, of course, was that the orbits of KBOs were entirely different from those in the solar system's inner and giant planet regions. Unlike the circular, low-inclination orbits closer to the Sun, orbits in the Kuiper Belt are mixed up and jumbled over one another. The entire structure has been puffed up into a fat disk that stretches more than 10 AU high.

But embedded within the orbital distribution of KBOs was another clue: Many of these objects orbit in lockstep multiples of Neptune's orbital period. For example, some make precisely 2 solar circuits for every 3 that Neptune makes. Astronomers knew long ago that Pluto inhabits such an orbit, but about 15 years ago, it became clear that Pluto had lots of company. Other flocks of KBOs orbit in 2:1, 5:3, and 7:4 orbital-period multiples, or resonances, with Neptune.



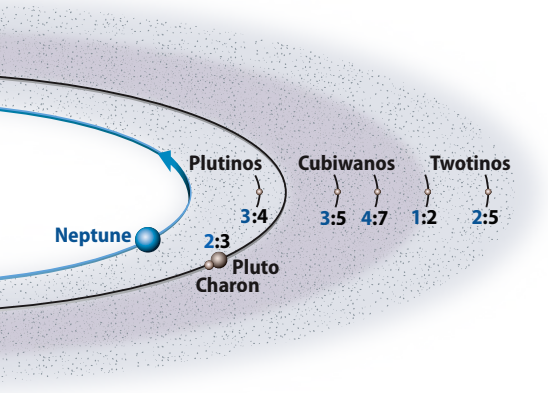
Michael Jäger

Mysterious Chiron orbits the Sun between Saturn and Uranus. This icy object's orbit isn't stable, however, which shows that it must have come from farther out in the solar system.

On the move

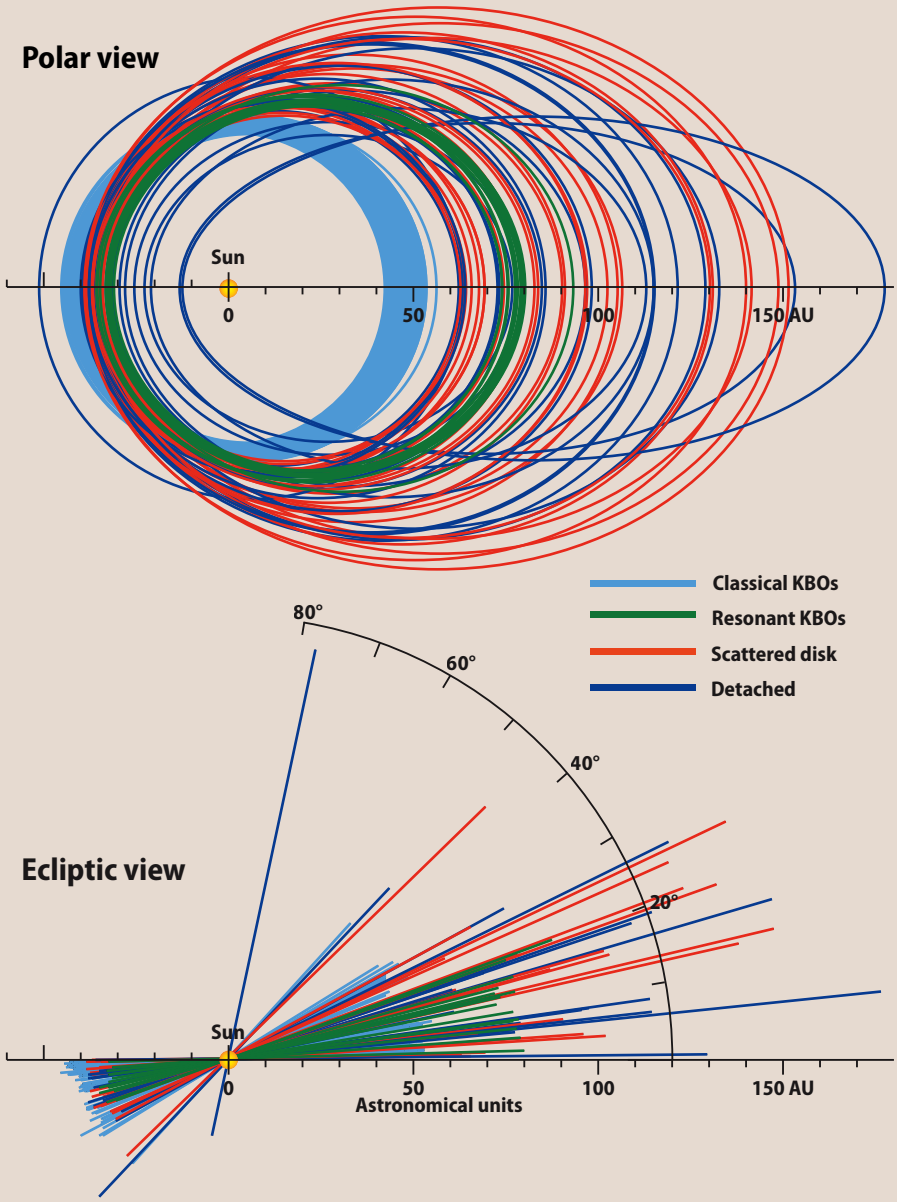
What could cause these resonant orbits? Dynamicists, led by Renu Malhotra of

Joined at the hip



Many Kuiper Belt objects orbit in lockstep with Neptune. Some, like Pluto, make two revolutions for every three of Neptune, but others exist in 2:1, 5:3, and 7:4 orbital resonances. *Astronomy*: Roen Kelly

The telltale orbits



Different populations of Kuiper Belt objects exist in the outer solar system. Classical KBOs are "cold" and have relatively low orbital eccentricities and inclinations, while those in the scattered disk are "hot" and form a fat disk more than 10 astronomical units high. *Astronomy*: Roen Kelly

the University of Arizona, realized that these resonances, when combined with the high eccentricities and inclinations of KBOs in these orbits, are the telltale signatures of planetary migration.

Amazingly, the Kuiper Belt was telling us something completely new: The giant planets had moved far from their birth locations. And, in doing so, they left clues in the distributions of KBO orbits. This was another revolution scored by studies of KBOs and the Kuiper Belt. Against all our preconceived, 20th-century notions, the biggest things in our planetary system have moved about.

More recent modeling has revealed that while Jupiter and Saturn have probably not migrated more than about 1 AU each, Uranus and Neptune could have traveled many AU from their birthplaces. In fact, they even might have been born in the space between Jupiter and Saturn.

And then the Kuiper Belt revealed yet another surprise. In 2000 and 2001, Hal Levison of the Southwest Research Institute and I, as well as Mike Brown of Caltech, found that there are two different populations of orbital inclinations in the Kuiper Belt. We found a dynamically "cold" population of low-inclination orbits that seemed to indicate these bodies formed in place. We also discovered a dynamically "hot" population of high-inclination bodies that looked like they had been transported into the region by dynamical effects, most likely the migration of the giant planets and the clearing of the giant planet zones after these outsized planets formed.

This odd forensic clue surprised us, but it was real. And the colors of KBOs support it, too. The hot population is redder on average than the more diversely colored cold population.

What about KBOs themselves?

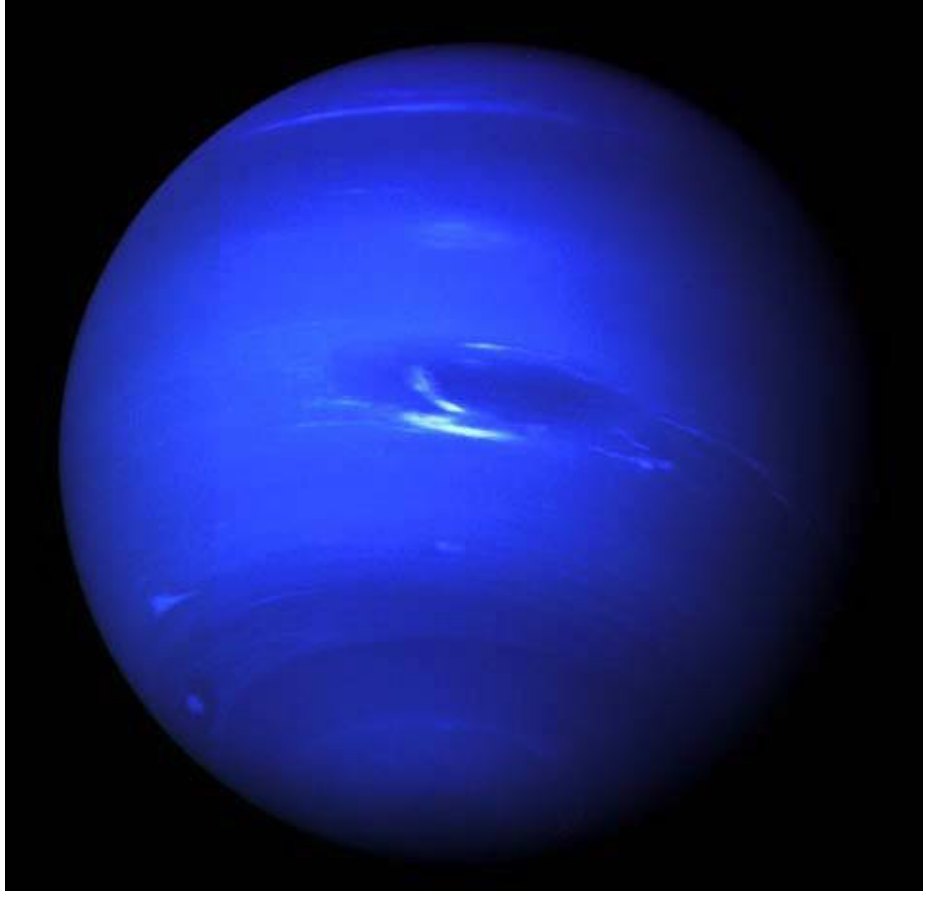
Most of the Kuiper Belt findings mentioned above concern the belt as an ensemble of bodies. The very existence of KBOs and details of their orbits provide clues to the architecture and origin of the outer solar system. As individual objects, however, KBOs are hard to study because they lie so far away and glow so dimly. Still, scientists have started to learn about their physical natures.

Observations show a wide range of characteristics. Some KBOs appear as dark as black velvet while others have the reflectivity of fresh ice. Some look as red as Mars while others display no color. Spectra show that water ice dominates the surfaces of some KBOs while others display ices of more exotic materials, such as methane, ethane, ammonium hydrates, carbon monoxide, and nitrogen. Pluto belongs to the nitrogen group.

Many KBOs have moons. Despite the present technological impediments to

spotting moons around these faint and distant objects, more than 20 percent of known KBOs have satellites. This includes the largest four: Pluto, Eris, Haumea, and Makemake. Several KBOs have more than one moon, with Pluto again being a prime example. As observing technology continues to improve, we expect to find fainter and fainter KBO companions. We may learn that most KBOs have moons and that those without satellites are rare.

Most KBO moons are small compared with their primaries. Still, several KBOs have moons at least half as large as the main object, making them binary systems. In 1978, Pluto was the first such binary discovered, although no one knew Pluto belonged to the Kuiper Belt back then. U.S. Naval Observatory astronomer James Christy first spotted Pluto's large moon Charon as an irregular blob on Pluto's limb in a fuzzy photograph of the distant world.



Neptune likely migrated from its birthplace, perhaps between Jupiter and Saturn, to its current orbit. Uranus probably suffered a similar fate. Astronomers first recognized the role of planet migration after studying the distribution of orbits in the Kuiper Belt. NASA/JPL

Into the future

Nearly 20 years after Dave Jewitt and Jane Luu discovered the Kuiper Belt, we now can see how deeply it has transformed our view of both the solar system's architecture and the nature of small planets.

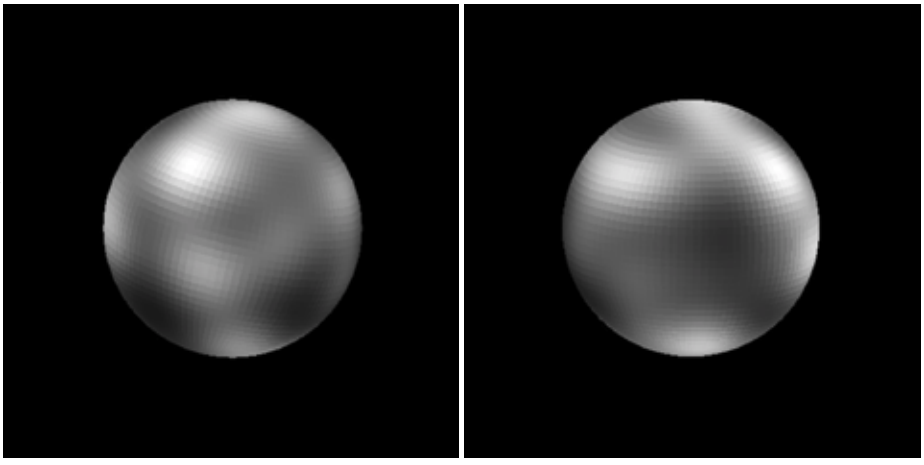
But many questions about the Kuiper Belt remain. Here are three of my favorites: Is the apparent edge of the Kuiper Belt around 55 AU from the Sun really its end, or is it just a gap between the Kuiper Belt we know and a still larger disk of bodies beyond? When and where did the cold and hot KBO populations originate? Do many KBOs have atmospheres, as Pluto does?

Scientists may answer these and many other questions within the next decade as powerful new tools come on-line. Those tools will help us probe deeper into the Kuiper Belt and study individual Kuiper Belt objects in more detail. The Panoramic Survey Telescope And Rapid Response System (Pan-STARRS) and Large Synoptic Survey Telescope (LSST) will reveal 10 or more times as many KBOs as we now know. And the Atacama Large Millimeter Array (ALMA) of radio dishes will make it possible to directly measure the sizes and albedos of thousands of KBOs. Today, we have that information for only a few dozen objects.

But the biggest step might be NASA's New Horizons mission. It will map, sniff, and probe the Pluto system in exquisite detail in 2015. Then, if all goes according to plan, the spacecraft will head off later this decade to flybys of one or two small KBOs lying farther from the Sun.

There's no doubt in my mind that when *Astronomy* magazine runs a follow-up to this article 7 to 10 years from now, we will likely have answers to many of today's Kuiper Belt puzzles.

But I for one don't believe we know yet what all the questions even are. So I fully expect that article to discuss new puzzles revealed by these and other tools that will explore the belt over the next decade. After all, that's the most alluring aspect of all scientific exploration: unraveling the mysteries that new data and new ideas generate as they transform our view of the solar system and cosmos we live in.



Alan Stern (SwRI)/Marc Buie (Lowell Observatory)/NASA/ESA

Pluto's surface shows bright and dark areas covered largely by nitrogen-rich ices. These depictions created from Hubble images show opposite hemispheres of Pluto and hint at this world's polar caps.

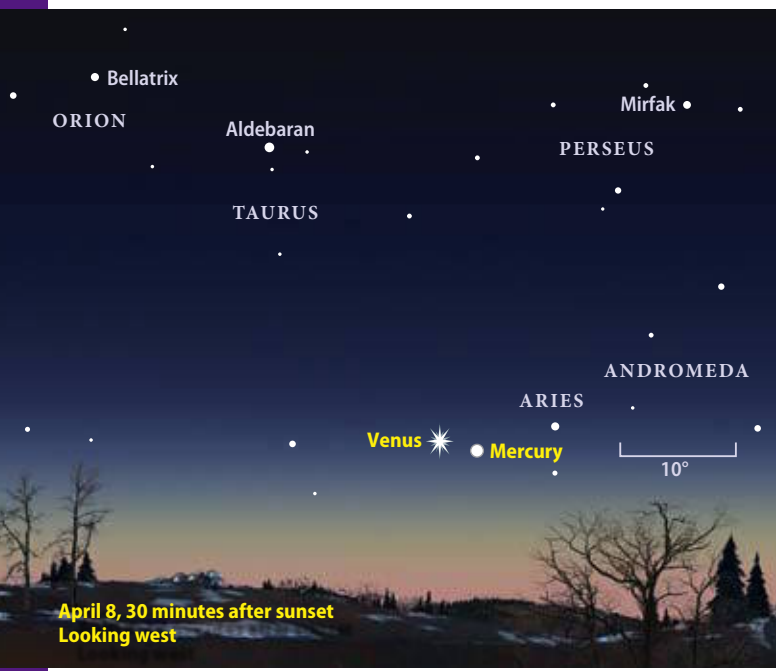
For a look at the New Horizons mission so far, visit www.Astronomy.com/toc.

The Sky this Month

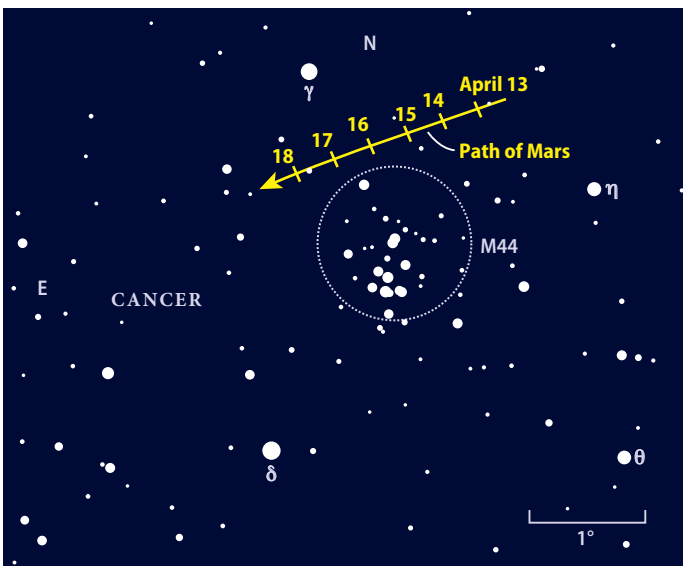
Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

April 2010

Saturn's display lasts all night



Venus points to Mercury in early April, serving as a helpful guide to the innermost planet. Then, in late April, Venus passes a few degrees south of the Pleiades star cluster (M45). *Astronomy*: Roen Kelly



The Red Planet slides north of the Beehive star cluster (M44) in mid-April. Binoculars and wide-field telescopes will provide the best views of this close conjunction. *Astronomy*: Roen Kelly

For many in the Northern Hemisphere, early April ushers in the first warm days of spring. This year, the warmer weather heralds excellent views of Mercury and Venus together in the evening twilight. High in the south, Mars commands attention as the brightest object in Cancer the Crab. And as the sky darkens, Saturn climbs in the eastern sky and remains visible all night.

After morning twilight commences, Saturn dips low in the west and Jupiter rises in the east. Toward the end of April, Capricornus rises early enough for a binocular view of Neptune. You won't want to miss it because this year the outer planet returns to the approximate spot where it was discovered in 1846.

Most of April's planetary activity takes place in the evening sky. We start with the year's best view of **Mercury**. Although the innermost planet has a reputation for being difficult to see, early April provides a helpful guide in the guise of brilliant **Venus**. On the 1st, with majestic Orion looking down on the western horizon, Mercury and Venus stand 3° apart. For the next 7 days, the two planets keep pace with each other as they climb away from the Sun.

Starting April 8, Mercury's smaller orbital path carries this planet back toward the Sun, and the angular distance between it and Venus grows. By April 14, their separation has doubled to 6°, and Mercury has faded to magnitude 1.2, making it hard to see in the twilight. Venus maintains a steady brightness, at magnitude –3.9, and continues to climb higher when viewed at the same time each evening.

Your last good chance to spot Mercury occurs April 15, when it lies less than 2° below a 1.5-day-old Moon. Look for the planet about 45 minutes after sunset, when it stands 7° high in the west-northwest. On the following evening, the Moon has moved to a spot 7° higher than Venus and just 3° below the Pleiades star cluster

— *Continued on page 41*

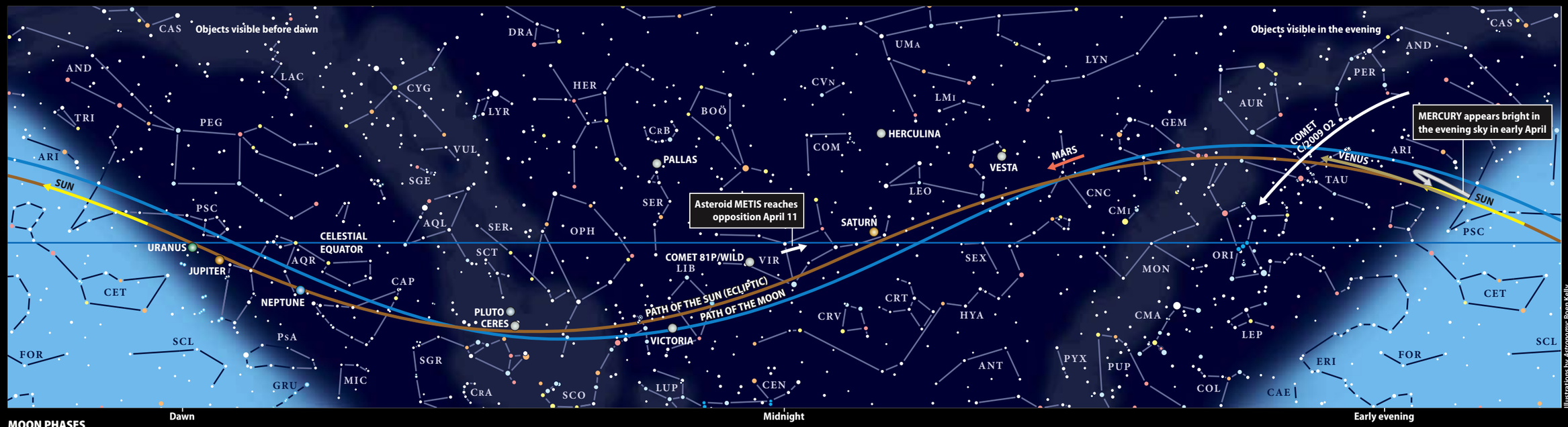
36 Mercury joins Venus
36 Mars buzzes the Beehive
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 Saturn's moons on the move
42 Comet search
43 Locating asteroids
43 Jupiter returns before dawn

Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in April 2010

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine



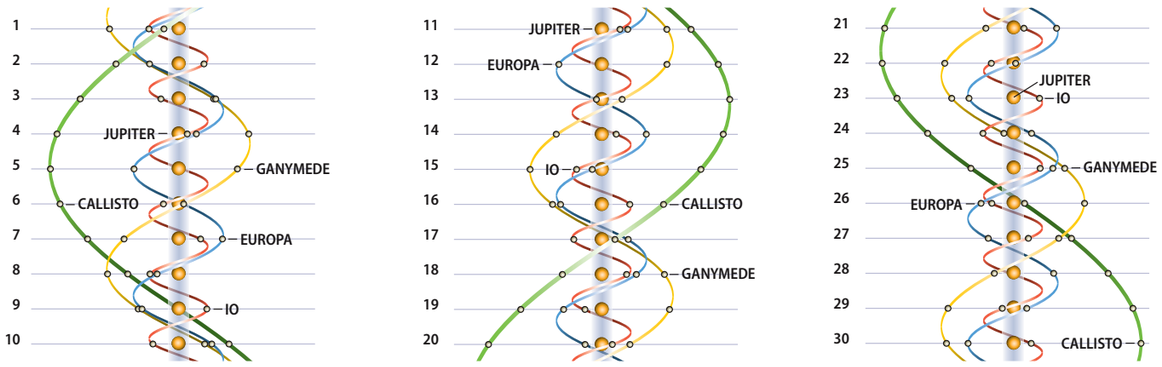
MOON PHASES

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	April 15	April 15	April 15	April 15	April 15	April 15	April 15	April 15	April 15
Magnitude	1.2	–3.9	0.4	8.4	–2.1	0.7	5.9	7.9	14.0
Angular size	9.1"	10.9"	8.2"	0.6"	34.1"	19.3"	3.4"	2.2"	0.1"
Illumination	21%	92%	90%	97%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.738	1.534	1.141	2.271	5.775	8.592	20.986	30.559	31.469
Distance (AU) from Sun	0.372	0.720	1.665	2.791	4.981	9.506	20.095	30.022	31.817
Right ascension (2000.0)	2h34.2m	2h59.6m	8h38.2m	18h16.8m	23h25.8m	12h01.7m	23h53.9m	22h01.2m	18h22.0m
Declination (2000.0)	18°19'	17°06'	21°03'	–21°59'	–4°47'	2°37'	–1°27'	–12°35'	–18°12'

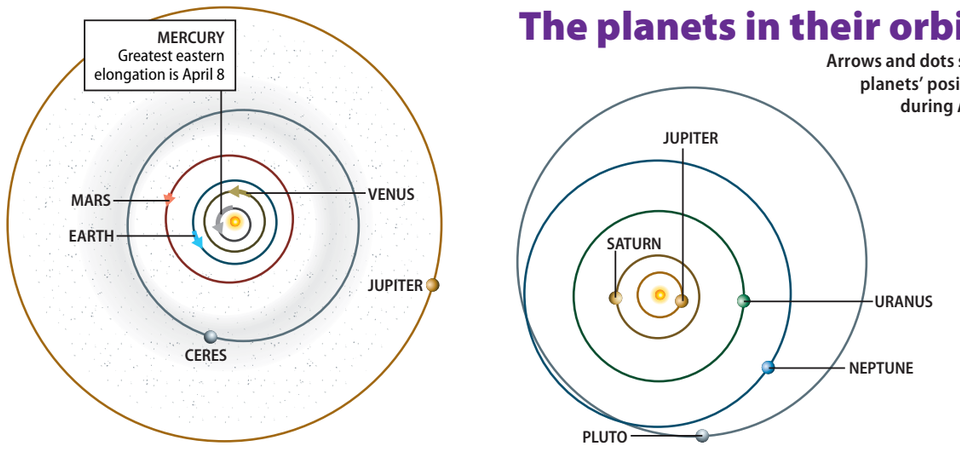
Jupiter's moons

Dots display positions of Galilean satellites at 6 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during April.



Path of the planets

StarDome

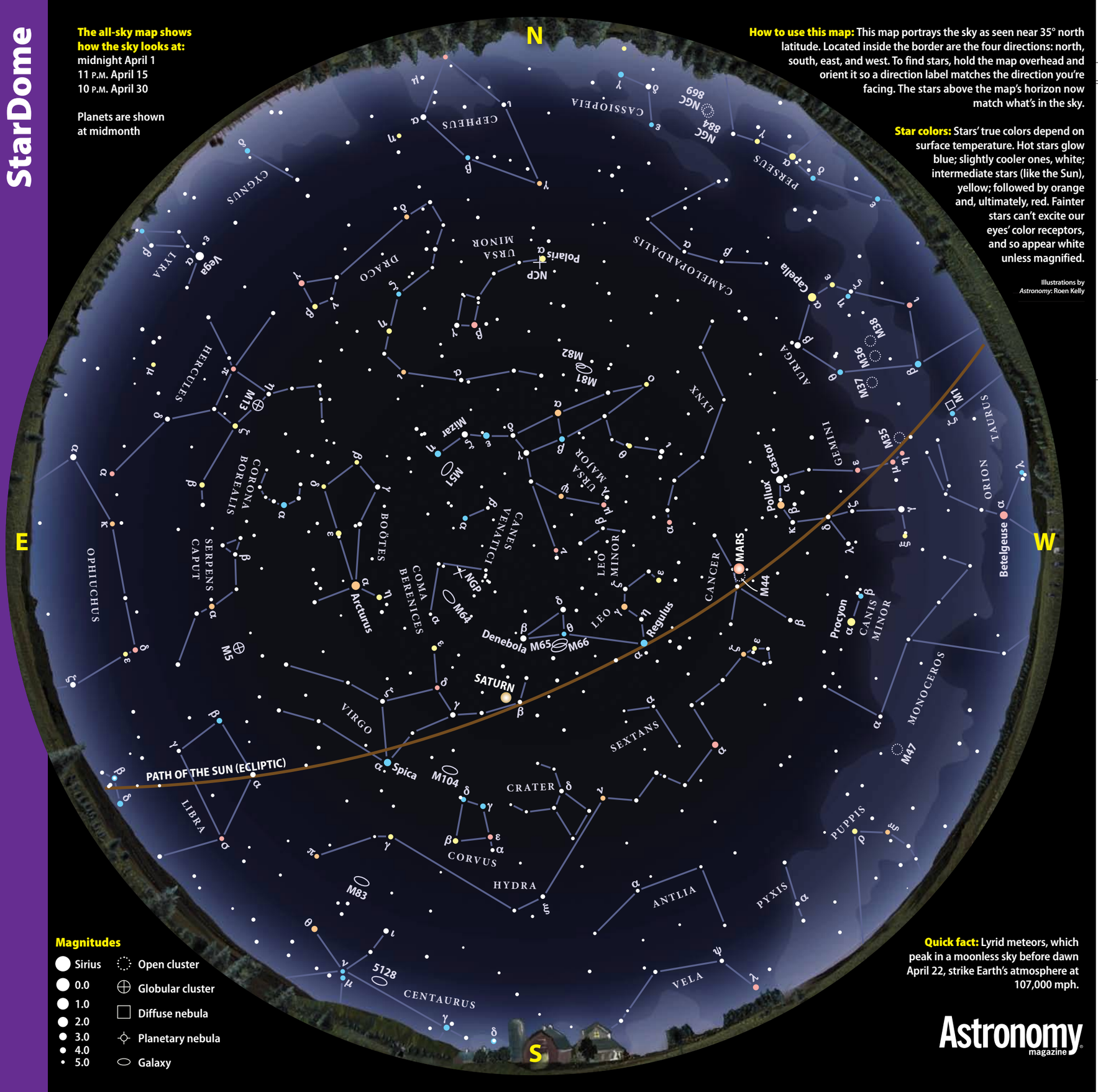
The all-sky map shows how the sky looks at:
midnight April 1
11 P.M. April 15
10 P.M. April 30

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: Lyrid meteors, which peak in a moonless sky before dawn April 22, strike Earth's atmosphere at 107,000 mph.

Astronomy magazine

April 2010

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

Calendar of events

6 Last Quarter Moon occurs at 5:37 A.M. EDT

Pluto is stationary, 9 P.M. EDT

7 Asteroid Vesta is stationary, 2 P.M. EDT

8 Mercury is at greatest eastern elongation (19°), 7 P.M. EDT

The Moon is at apogee (251,657 miles from Earth), 10:44 P.M. EDT

Special observing date

8 Mercury makes its best evening appearance of the year for Northern Hemisphere observers.

9 The Moon passes 4° north of Neptune, 9 P.M. EDT

11 Asteroid Metis is at opposition, 8 A.M. EDT

The Moon passes 6° north of Jupiter, 6 P.M. EDT

12 The Moon passes 6° north of Uranus, 10 A.M. EDT

14 New Moon occurs at 8:29 A.M. EDT

15 The Moon passes 1.5° north of Mercury, 7 P.M. EDT

16 The Moon passes 4° north of Venus, 9 A.M. EDT

18 Mercury is stationary, 6 A.M. EDT

21 First Quarter Moon occurs at 2:20 P.M. EDT

22 The Moon passes 5° south of Mars, 5 A.M. EDT

Lyrid meteor shower peaks

24 The Moon is at perigee (228,131 miles from Earth), 5:00 P.M. EDT

25 The Moon passes 8° south of Saturn, 8 P.M. EDT

28 Full Moon occurs at 8:18 A.M. EDT

Mercury is in inferior conjunction, 1 P.M. EDT

29 Asteroid Ceres is stationary, 1 A.M. EDT

See tonight's sky in Astronomy.com's STARDOME

— *Continued from page 36*

(M45) — a stunning sight in late twilight and a scene worth photographing.

Through a telescope, Mercury varies noticeably during April's first 2 weeks. It begins the month as a tiny disk just 6" across and 67 percent lit. But Mercury's orbital motion brings it closer to Earth and closer to a line between the Sun and Earth. By April 15, Mercury's apparent diameter has increased 50 percent, to 9". But the sunlit portion of the disk diminishes throughout early April. It drops to half-lit April 5 and to only 18 percent lit April 15.

Changes in Venus' appearance take place more leisurely. On April 1, the bright planet shows a 10.5"-diameter disk that's close to full phase (95 percent lit). By the end of the month, it has grown to 11.4" across, and its phase has decreased to 89 percent lit. The "evening star" passes 4° south of the Pleiades April 24, and it remains close to the star cluster for a few days. It continues its trek across Taurus the Bull for the rest of April and well into May.

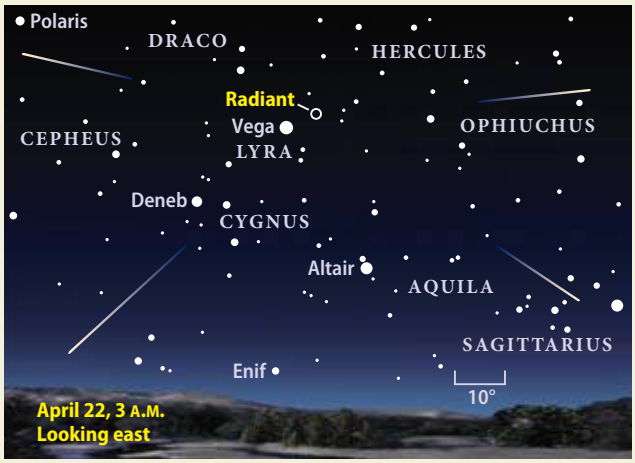
After darkness falls, look high in the southwest (three-quarters of the way to the zenith) to find **Mars**. When April begins, the Red Planet gleams at magnitude 0.2 and easily dominates its host constellation, Cancer the Crab.

As Mars moves slowly eastward relative to the background stars, it slides 1° north of the Beehive star cluster (M44) in mid-April. The pair will make a fine sight through binoculars or a low-power, rich-field telescope. A First Quarter Moon passes 5° below Mars April 21.

As the month winds down, the planet approaches Cancer's border with Leo the Lion. By April 30, Mars has faded noticeably, to magnitude 0.7, yet it still outshines Leo's leading star, Regulus, by more than half a magnitude.

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Lyrid meteor shower peaks before dawn April 22, when viewers under a dark sky may see 25 meteors per hour. *Astronomy:* Roen Kelly

Prime conditions await the Lyrids peak

The Lyrid meteor shower remains active from April 16 to 25, reaching its peak before dawn April 22. For observers in North America, the First Quarter Moon sets before 3 A.M. local daylight time. An hour later, the radiant (which lies in the constellation Lyra the Harp) passes nearly overhead.

This allows observers under a dark sky to see close to the maximum number of Lyrid meteors possible, between 15 and 25 meteors per hour. The observed rate for most meteor showers falls below the so-called zenithal hourly rate — the rate an observer would see under a dark sky if the radiant lies overhead — because the radiant appears much lower.

Astronomers do not predict an unusually strong Lyrid shower this year. The shower doesn't always follow predictions, however. During a spectacular show in 1982, it produced a short-lived peak of up to 90 meteors per hour.

Rising **Moon**

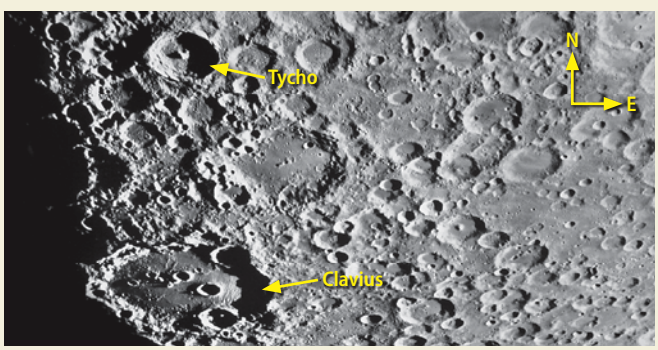
Age and youth meet in the lunar highlands

Two longtime favorites of Moon watchers stand out in our celestial neighbor's southern half starting April 22. As the Sun rises over the craters Tycho and Clavius, it creates a magnificent play of shadow and light. Although Tycho's brilliant ray system doesn't come into view until a few nights later, its deep bowl, sharp rim, and well-defined central peak make it prominent nonetheless.

Clavius is the huge ring that lies closer to the lunar limb. Its softer rim is a telltale sign of the prolonged battering it has suffered from debris left over from the solar system's construction. Take a close look inside its shallow bowl, and you'll see a neat curving chain of smaller impact craters. Over the course of an hour or two, watch the shadows retreat and reveal still-smaller craters.

On the following nights when Tycho's rays become obvious, look for a darker ring surrounding its raised rim. The heat from the blast that gouged out this crater caused the surrounding surface to partially melt, losing its lighter shade.

Although Tycho's distinct shape fades from prominence as the Sun climbs higher in the lunar sky, Clavius never gets lost. However, the smaller craters nearby that were obvious at sunrise now appear as just a parade of potholes.



Lunar craters Tycho and Clavius offer a nice contrast of youth and age. Young Tycho sports a sharp rim and central peak while ancient Clavius reveals several later impacts. *Consolidated Lunar Atlas*/UA/LPL

For a predawn treat April 3, watch the double star Sigma (σ) Scorpii (just west-northwest of Antares) pop back into view. It reappears on the Moon's dark limb around 3 A.M. EDT. For observers on a line from Kansas to southern Georgia, the Moon's mountains and valleys make the bright stellar pair wink off and on multiple times. This spectacular grazing occultation will be worth an hour's drive.

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Mars (west)	Jupiter (east)
Venus (west)	Saturn (south)	Saturn (west)
Mars (southwest)		Uranus (east)
Saturn (southeast)		

When viewed through a telescope, Mars shows a small disk. And the reddish orb shrinks throughout April, from 9" across in early April to 7" by month's end. You'll need an 8-inch or larger scope to see much detail on the planet's surface. The north polar cap remains the most conspicuous feature.

The best time to view Mars is when it lies high in the sky shortly after darkness falls. The planet remains visible until well past midnight.

April offers an easy chance to spy an asteroid through binoculars. **Vesta** glows at 7th magnitude this month and lies near a convenient guide star. In early April, you can find the asteroid just 1° from 3rd-magnitude Epsilon (ε) Leonis, the westernmost star in Leo's Sickle asterism. Vesta moves slowly to the southeast after April's first week, but, even by month's end, it lies only 3° from the star.

The majestic ringed planet, **Saturn**, stands well above the southeastern horizon at nightfall. It appears among the stars of Virgo the Maiden. Shining at magnitude 0.7, Saturn appears a bit brighter than Virgo's luminary, Spica. Notice the different colors of Saturn and Mars. Saturn's clouds reflect a generally yellowish hue while Mars' surface appears orange. Watch Saturn rise with a waxing gibbous Moon April 25.

Saturn's moon Iapetus brightens noticeably this month, although it becomes easier to find around April 20 when the ringed planet's brightest moon, Titan, lies nearby. *Astronomy*: Roen Kelly

Saturn reached opposition and best visibility March 21, so it remains near its peak and on display nearly the whole night throughout April. The best views through a telescope, however, come when it lies high in the sky around local midnight. In mid-April, Saturn's disk measures 19" across the equator, and its rings span 44". The rings tilt 2° to our line of sight and have their northern face on display.

Saturn's largest moon, Titan, completes two orbits of the giant planet each month. The 8th-magnitude moon spends April's first week west of Saturn. It then passes the planet and flips to its eastern side April 7. Titan lies close to 10th-magnitude Rhea April 8.

Titan returns to Saturn's vicinity April 14, then swings to its west before coming back April 22. It remains east of the planet from the 23rd through the end of the month.

Saturn's outer moon Iapetus offers a unique observing experience: It is the only solar system moon that brightens and dims markedly as it orbits

Comet search

Catalina crowns a sparkling star cluster

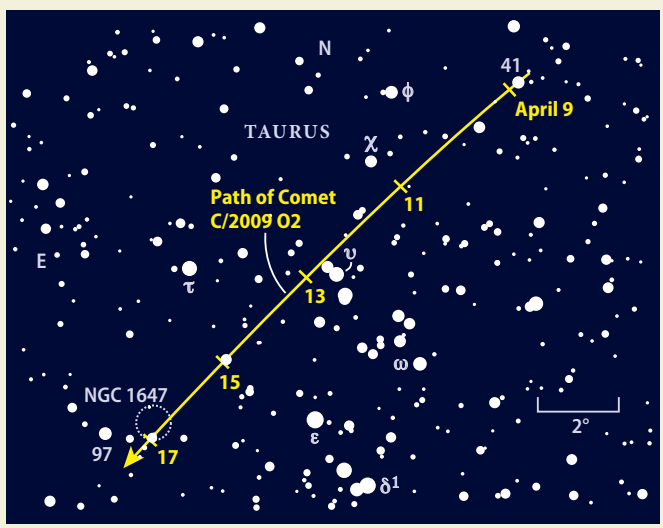
Spark your love for observing with an evening cruise to Catalina. All you need to capture Comet C/2009 O2 (Catalina) is a 4-inch telescope under a rural sky. The comet gracefully arcs above the Pleiades and Hyades star clusters on its way to Orion. Make sure it's near the top of your observing list because it sinks quickly into the western horizon haze after darkness falls.

Astronomers expect this modest comet to glow around 9th magnitude. That's faint enough that you'll want to schedule your observing around the Moon, which means the first half of April will be prime comet-hunting time. If you return to Catalina the weekend of April 16, the small fuzzball contrasts nicely with the spread-out sparkles of distant star cluster NGC 1647.

On Friday evening, the two lie 1° apart, well-suited for viewing through a wide-field scope. The comet and cluster appear even closer Saturday evening. The crescent Moon displays stunning earthshine April 17, but after that, the lunar light interferes with Catalina.

If you zoom in with your telescope, you'll see that the comet's inner region brightens to a point. This is what observers call the "false nucleus." The comet's true surface remains hidden within the compact cocoon of dust astronomers call the coma.

All too soon, Catalina plunges through the solar system's normal playing field, the ecliptic, and enters the southern sky. It will disappear for northern observers before summer arrives.



Comet C/2009 O2 (Catalina) glows at 9th magnitude among the stars of Taurus. It passes within 1° of star cluster NGC 1647 in mid-April.

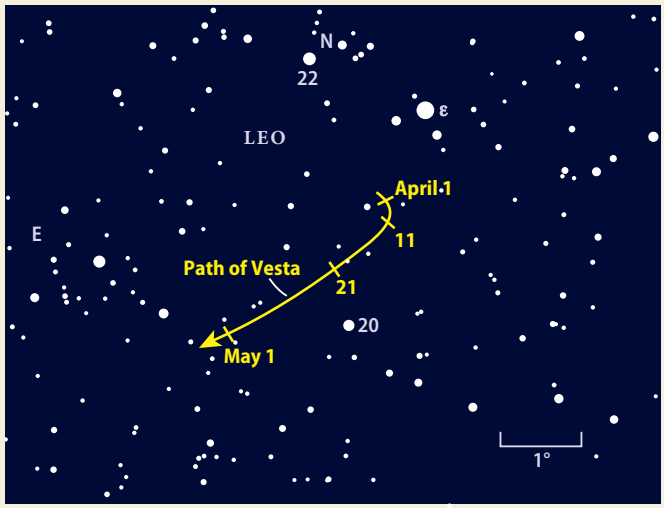
If Catalina whets your appetite, you might want to track down Comet 81P/Wild. It glows between 9th and 10th magnitude during April. You can find this periodic visitor within a few degrees of the 4th-magnitude star Iota (ι) Virginis all month.

Vesta journeys through Leo the Lion

Long before star charts and written words, skywatchers noticed the planets. These "wanderers" moved back and forth and executed graceful loops against the fixed background of stars. Asteroids share this behavior, which results when Earth catches up to and passes these outer worlds as we cruise around the Sun. The main-belt asteroid 4 Vesta is just completing its loop and starting to move eastward again. It will take a week or so to notice its shift relative to the stars instead of every other night.

Vesta lies high in the south as darkness settles in. You can find it easily just below the tip of Leo the Lion's Sickle asterism — the group of stars that resembles a backward question mark. The 320-mile-wide asteroid can be viewed through binoculars away from bright city lights. With only a few neighboring stars brighter than this 7th-magnitude world, you can quickly identify it from its position plotted on the chart at right.

By next month, Vesta will have faded by about 50 percent as Earth increases its lead on the faster inside lane of the solar system racetrack. In Roman mythology, Vesta is Zeus' sister, the goddess of the hearth and home.



Vesta moves slowly against the background stars of Leo the Lion throughout April. Use 3rd-magnitude Epsilon (ε) Leonis to guide you to the 7th-magnitude asteroid. *Astronomy*: Roen Kelly

its planet. During April, you can watch Iapetus brighten as it moves from east to west of Saturn. It glows dimly at 12th magnitude in early April when it lies 9' east of the planet. Titan joins Iapetus April 11, when the brighter moon reaches greatest eastern elongation. Iapetus then lies to Titan's southeast, and the two satellites maintain a similar configuration for a couple of days as both move westward relative to Saturn.

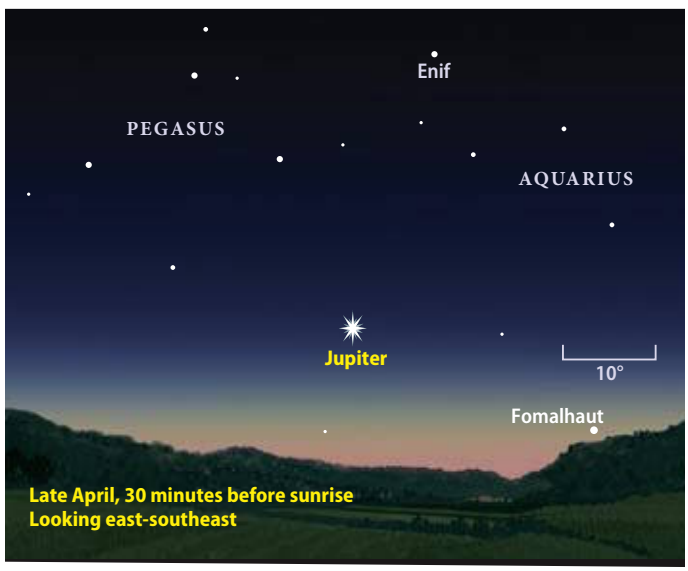
On April 17, Iapetus lies 1.4' due south of Saturn while Titan has moved to Saturn's west. The two moons meet again April 20, when Iapetus passes south of Titan. The outer moon then appears noticeably brighter than it did when April began, but it improves even more by month's end, when it lies well west of Saturn.

The brightening occurs because one hemisphere of Iapetus reflects 90 percent of sunlight while the other half reflects barely 10 percent. The brighter side directly faces Earth when Iapetus lies farthest west of Saturn.

Although Titan and Iapetus rank as Saturn's most intriguing moons, they aren't the only ones worth viewing. The ringed planet boasts three 10th-magnitude moons — Tethys, Dione, and Rhea — that show up through most backyard scopes.

You will have to wait for dawn's approach to see the rest of the planets. By the end of April, **Neptune** rises in a dark sky. The distant object crossed from Capricornus into Aquarius in March and now lies near the location where it was discovered 164 years ago. Neptune has completed nearly one full orbit of the Sun since German astronomer Johann Galle first spotted it from the Berlin Observatory September 23, 1846.

On April 30, you can recreate Galle's discovery. Neptune then lies in Aquarius, approximately midway between the 5th-magnitude stars Mu (μ) Capricorni and 38 Aquarii. Neptune glows at magnitude 7.9, so you'll need binoculars or a telescope to spot it. A waning crescent Moon lies 6° to Neptune's upper right before twilight begins April 9.



Jupiter climbs out of the predawn twilight and appears against a darker sky as April progresses. By the end of the month, the giant planet appears brighter than any star. *Astronomy*: Roen Kelly

Jupiter rises shortly before the Sun, in bright twilight April 1 and in a darker sky by month's close. You can spot it easily above the eastern horizon by 5 A.M. local daylight time April 30. It then shines at magnitude –2.1, making it the brightest point of light in the sky. On April 11, a waning crescent Moon rises 30 minutes before Jupiter. As twilight paints the sky, the two objects make a pretty pair in the east.

Uranus lurks in Jupiter's vicinity but proves much harder to find. The distant planet lies 5° to Jupiter's lower left in late April. The brightening twilight makes it hard to spot 6th-magnitude Uranus even through binoculars. It will become an easier target by late May.

Who was Thomas H

England's contemporary of Galileo observed the Sun, the Moon, and Jupiter's satellites through an early telescope. **by Dan Falk**

Last year marked the 400th anniversary of Galileo's revolutionary telescopic observations. But at the same time Galileo was observing from Italy, an Englishman named Thomas Harriot was turning a similar instrument skyward. Harriot was a keen observer of the heavens as well as one of the most important mathematicians of his day. While Galileo became a household name, few today have heard of Thomas Harriot. In spite of his many contributions, he remains a neglected figure in the history of science.

Part of the reason for his relative obscurity is that Harriot, unlike his better-known contemporaries, published little. Only one completed work appeared in his lifetime — a report from his voyage to North America. His important book on algebra, known as the *Artis analyticae praxis* ("The application of the analytic art"), or *Praxis* for short, appeared in print after his death. But the vast majority of his scientific work — including his astronomical observations — exist only in manuscript form.

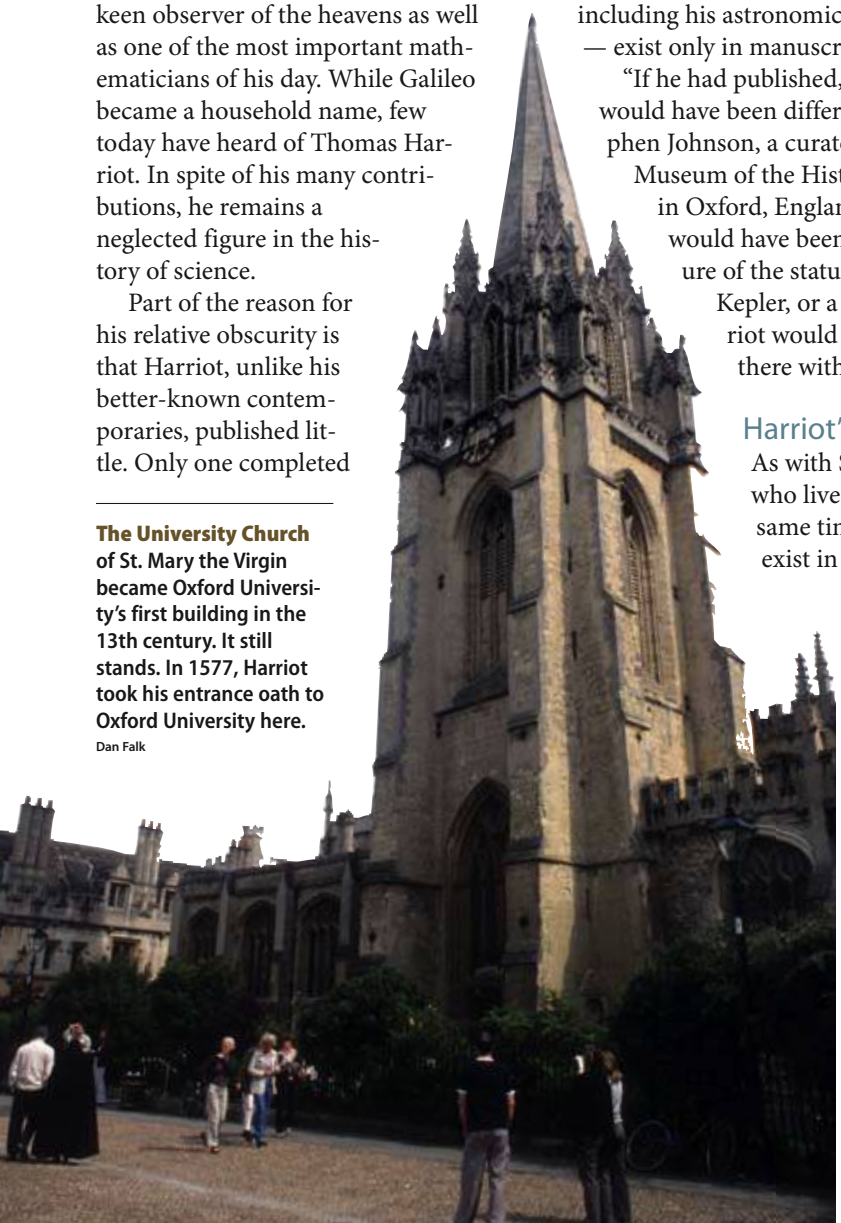
"If he had published, the story would have been different," says Stephen Johnson, a curator at the Museum of the History of Science in Oxford, England. "I think he would have been seen as a figure of the status of a Galileo, a Kepler, or a Descartes. Harriot would have been up there with them."

Harriot's early years

As with Shakespeare, who lived at about the same time, many gaps exist in our knowledge of Harriot's life. He was born probably in or near Oxford in 1560. He enrolled at the university at the age of 17, taking his entrance oath at the Church of St. Mary the Virgin. He lived and studied nearby, at St. Mary's Hall. The church is still there and appears much as it did in Harriot's day. St. Mary's Hall — not actually a building but rather a kind of "collective" — has since become part of Oriel College.

Harriot graduated from the University of Oxford in 1580. He moved to London, and a few years later he began working for Sir Walter Raleigh, teaching mathematics and navigation to Raleigh's sailors. In 1585, Harriot sailed to Virginia with a group of colonists to document and describe the new lands.

Harriot turned out to be an acute observer. He described in detail the vegetation, animal life, and natural resources of the land, and he took an intense interest in the indigenous people that he encountered. He studied native customs and religious practices, and he learned the Algonquin language — even develop-



The University Church of St. Mary the Virgin became Oxford University's first building in the 13th century. It still stands. In 1577, Harriot took his entrance oath to Oxford University here.
Dan Falk

Dan Falk

Harriot studied in St. Mary's Hall, once part of the Church of St. Mary the Virgin in Oxford. St. Mary's Hall is now part of Oriel College.

arriot?

This portrait, completed in 1602, hangs in Trinity College in Cambridge. It appears to show English scientist Thomas Harriot. Recent studies have cast doubt on the identity of the man pictured, and historians no longer believe this to be Harriot. Unfortunately, no other image of him exists.
Trinity College, Oxford/Galaxy

ing a system for transliterating Algonquin words so they could be written down.

The yearlong expedition must have been an eye-opening experience for Harriot. "To think of a young man who had been trained as a scholar — he had been in a cloistered environment — to be propelled into this completely different world; I think it set him up as a different sort of person for the rest of his life," says Johnson. "I think it probably contributed to the nature of his intellectual inquiry, to question the normal understanding of how things work."

Harriot's observations appeared in his *A Briefe and True Report of the New Found Land of Virginia*, published in 1588 — the first book about the New World printed in English. Artist John White, whose detailed sketches appear alongside the scientist's text in *A Briefe and True Report*, accompanied Harriot. The book was partly propaganda — one of its aims was to encourage settlement, portraying the new lands as bountiful and rich. Yet Harriot himself engaged the new land and its people more than many other early European visitors.

"He took a far broader perspective on the people he met in the New World than most of his contemporaries, who were really there either in a 'get rich quick' way — finding gold and things like that — or who just wanted to think of the practicalities of cultivating and establishing crops there," says Johnson. "Harriot seems to have been genuinely interested in the tribes that he met and their way of life."

Dan Falk *is a science journalist based in Toronto. His second book,* In Search of Time *(Thomas Dunne Books), appeared in 2008.*

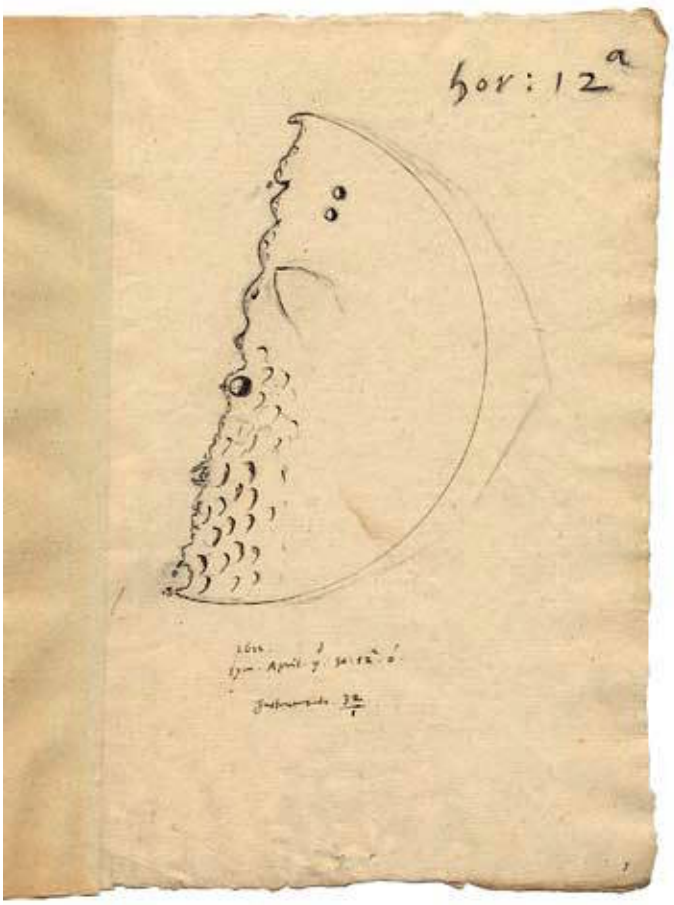
On his return to England, Harriot continued to work for Raleigh. He lived briefly in Ireland, where he administered one of Raleigh's estates. He then returned to London, where, beginning in 1595, he found employment with a new patron, Henry Percy, the Ninth Earl of Northumberland, known as "the Wizard Earl" because of his passion for science.

Observing the heavens

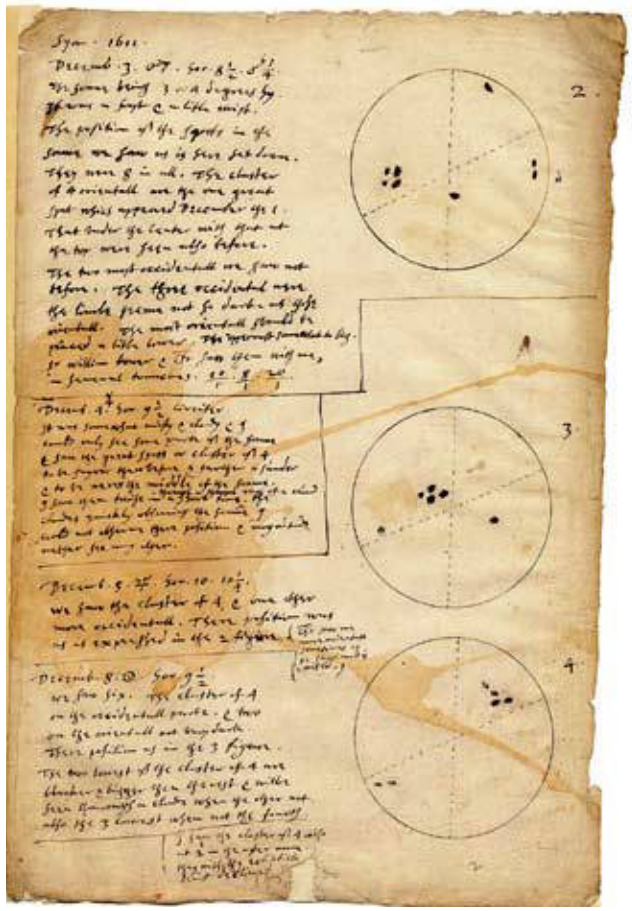
During the next decade or so, Harriot developed a keen interest in astronomy. In 1607, he observed the comet now known as Halley's Comet (long before Halley's birth). Soon — the exact date is unknown — he began to use a new invention from Holland, the telescope, to study the night sky. Beginning in 1609, he sketched the Moon's surface and observed sunspots, determining the Sun's rotational speed. He also observed the four bright moons of Jupiter and calculated their orbits.

These events occurred around the same time Galileo was making his groundbreaking observations in Italy. Those observations would end up in *Sidereus Nuncius* ("The Starry Messenger"), which appeared in 1610. Galileo's book became a bestseller across Europe and made the Italian professor a celebrity.

But can we determine who made the first telescopic observations? "It's entirely possible that Harriot did it before Galileo; it's entirely possible he did it after Galileo," says historian Scott Mandelbrote of the University of Cambridge. "It's pretty much certain that they didn't know that the other one was doing it. And it's



The First Quarter Moon appeared cratered and irregular to Harriot as he observed it through his simple telescope. He made this sketch April 9, 1611. Because England used the Julian calendar until 1752, this date translates to April 19 under our current Gregorian calendar system. Lord Egremont/Galaxy



These drawings of the Sun, which Harriot made in December 1611, show sunspots. By studying their positions, Harriot calculated the Sun's rotational rate. He made 199 observations of sunspots between December 8, 1610, and January 18, 1613. Lord Egremont/Galaxy

equally possible that other people were doing it, about whom we don't know."

The problem is difficult on both accounts: We don't know the exact dates on which Harriot observed. As for Galileo, although specific dates appear in *Sidereus Nuncius*, some historians view them with skepticism. "I don't think one can view *The Starry Messenger* as being a diary of Galileo's engagement with the telescope," says Mandelbrote. "This is very clearly a constructed account of a series of observations that are designed to lead to a particular outcome. … One might be skeptical about the timetable."

We do know that between 1610 and 1613 Harriot made numerous astronomical observations. He carried out most of them from the grounds of Syon House, Northumberland's grand estate near Richmond, on the outskirts of London. During that period, he made detailed maps of the lunar surface, produced nearly 100 drawings of Jupiter with its satellites, and created several dozen drawings of the Sun's surface. He also corresponded with other like-minded scientists of the day, including German mathematician Johannes Kepler (at that time living in Prague), with whom he discussed optical theory and techniques for building telescopes.

Harriot appears to have embraced the Copernican view, which places the Sun in the center of the solar system, as well as the atomic theory of matter first proposed by the early Greek philosophers. Of the two, atomism was the more problematic, as it was inevitably linked to atheism, which was, at that time, a criminal offense in England.

Mathematical triumphs

Harriot's work in mathematics had more of an impact than his astronomical work. In the *Praxis*, he sets out methods for solving polynomial equations and introduces the "greater than" (>) and "less than" (<) algebraic symbols, as well as the modern symbol for "square root" (√).

"Harriot's principal contribution — the contribution for which he should be remembered — is that he was the first mathematician to use a pure symbolism," says Muriel Seltman, a mathematician and historian from the University of Greenwich (now retired). Until that time, Seltman says, mathematicians typically used abbreviations, short forms of Latin words. The move to symbolism was revolutionary. "It democratizes mathematics," she says. "It makes algebra available to a vast number of people who couldn't otherwise have understood it."

Harriot also studied the parabolic paths of projectiles and determined the densities of numerous materials. He studied optical phenomena and understood the principles behind the rainbow. He independently discovered Snell's Law, which governs the refraction of light.

Politics, later life, and honors

Matters of state held little interest for Harriot, but he nonetheless got swept up

in the political turmoil of the early 17th century. Opponents linked his second patron, Northumberland, to the Gunpowder Plot of 1605. A relative, Thomas Percy, was one of the five conspirators in the attempt to blow up Parliament; Northumberland, considered guilty by association, spent 17 years in prison. Officials jailed Harriot but released him after a few weeks. Still, they regarded his activities with suspicion.

His first patron, Raleigh, fared much worse. Imprisoned several times in the Tower of London for a variety of alleged crimes, authorities finally beheaded him for treason in 1618.

Seltman discovered a twist on this story when looking through Harriot's correspondence. The court delayed Raleigh's execution by several days so that the great poet and explorer could have one last conversation with Harriot. "Now, this is a total mystery," says Seltman. "What did they want to talk about? Not, I'm sure, quadratic equations."

Harriot died in 1621 from a painful and rather unusual affliction — cancer of the nostril, likely caused by years of smoking. He was buried at the Church of St. Christopher-le-Stocks in London. Sadly, the building burned to the ground in the Great Fire of London in 1666.

A small commemorative plaque, which once stood near the site of the church, now lies a short distance away in the lobby of the Bank of England. This plaque — in a part of the bank not open to the public — was England's only memorial to Harriot until July 26, 2009, when Lord Egremont unveiled a new memorial in Syon Park. An annual lecture series held at Oxford, however, also commemorates Harriot.

In the United States, the National Park Service commemorated Harriot at Roanoke Island in North Carolina. Adjacent to the reconstructed Fort Raleigh is "Harriot's Walk," which leads visitors along a path among many of the trees and plants originally identified by the Englishman as he surveyed his new world. Plaques display Harriot's comments about these new findings as he saw them in 1585 and 1586.

The debate continues

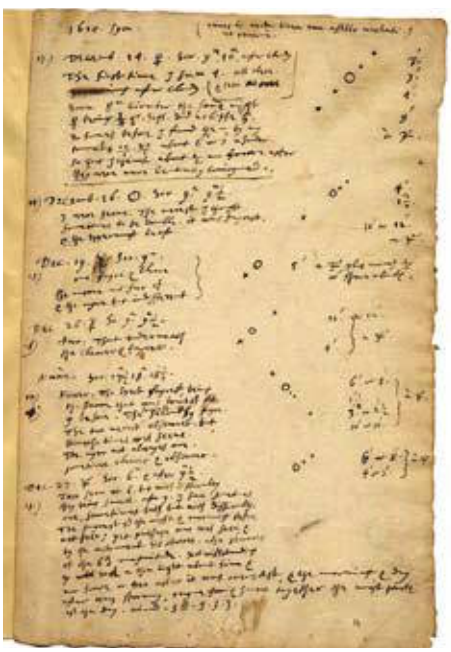
Scholars continue to debate Harriot's place in the history of science. Some, like Seltman, believe he has been unfairly overlooked. "Thomas Harriot was the greatest mathematician and scientist in England before Newton," she says. Even though he is "not of the same stature as Newton, Copernicus, Kepler, and Galileo," he was "immensely important for the mathematical and scientific development of this country."

Harriot was undoubtedly a skilled mathematician and a gifted observer, says Mandelbrote, but he never wrote (and certainly never published) a truly groundbreaking work. Therefore, Harriot can't be considered a true equal of Galileo, Kepler, or Tycho Brahe. "The thing that all of those men have in common — and that Harriot doesn't have — is the composition of a treatise which uses mathematical learning, particularly with reference to astronomy, to challenge philosophical concepts," he says. "This is something which Harriot simply does not do. He may have had the mathematical learning; he may have had the philosophical insights. But he didn't write 'the book.' "

Adds Johnson: "He was clearly extraordinarily curious. He must have recognized some of the implications of what he was seeing — but he decided that it wouldn't go into the public sphere. So he took a different course."

Dan Falk

This commemorative plaque originally stood near the Church of St. Christopher-le-Stocks in London, where Harriot was buried. Fire destroyed the church in 1666, so the plaque now sits in the lobby of the Bank of England.



< Harriot observed Jupiter and its satellites numerous times, first training a telescope on it in October 1610. He made these sketches in December of the same year. Lord Egremont/Galaxy

V Syon House, the estate of the Duke of Northumberland, sits in West London. It was from here that Thomas Harriot observed the heavens between 1610 and 1613. Dan Falk

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Ask Astro

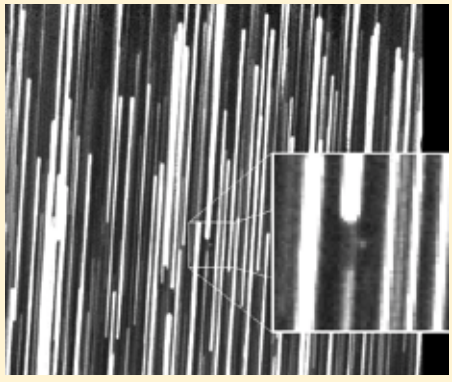
Astronomy's experts from around the globe answer your cosmic questions.

Is another Moon possible?

Q: Could a near-Earth asteroid enter into orbit around Earth? — Mark Phelan, Abilene, Texas

A: While the Moon is Earth's only known natural satellite, a few small near-Earth asteroids have become temporary Earth satellites.

In 2002, we thought we had found one such small Earth-orbiting asteroid when amateur astronomer Bill Yeung discovered a near-Earth object with a 48-day orbital period about the planet. However, Paul Chodas of NASA's Jet Propulsion Laboratory suggested that this Earth orbiter might be the third stage (S-IVB) from the Saturn V rocket that helped launch Apollo 12 astronauts to the Moon in November 1969. University of Arizona astronomers Carl Hergenrother and Rob Whiteley observed the object's spectral characteristics and noted that they are consistent with white titanium oxide paint — the type NASA used on Apollo Moon rockets 40 years ago.



In June 2006, Earth captured tiny asteroid 2006 RH_{120}. This space rock became a temporary Earth satellite, sticking around for roughly 1 year.
Peter Birtwhistle, Great Shefford Observatory

In June 2006, Earth captured a tiny 16-foot-diameter (5 meters) asteroid called 2006 RH_{120} from a heliocentric orbit that was just barely outside that of Earth. The asteroid then looped around the planet in a near polar orbit that took it beyond the Moon's distance at the orbit's farthest point. Thirteen months later, 2006 RH_{120} escaped back to a heliocentric orbit. The asteroid spent only a relatively short time as an Earth satellite.

However, if a massive third body, like the Moon, gravitationally nudged a small object, or if an asteroid-Moon collision ejected an object from the Moon's surface, it could then become a long-term Earth satellite. — Don Yeomans, NASA's Jet Propulsion Laboratory, Pasadena, California

BLACK HOLE DINNER

Q: If our galaxy's central supermassive black hole devoured a star, what effects or phenomena would be visible to observers on Earth? How likely is this sort of event to happen within a few human lifetimes? — Ron Pridgen, Liberty, Missouri

A: If a star like the Sun orbited close to the galaxy's central supermassive black hole, the black hole's strong gravitational tidal forces could tear the star apart. How close is too close? A Sun-like star would have to approach the black hole at about ¾ of the Earth-Sun distance. **Unless the number of stars near the galactic center is extremely high, that is not likely to occur more than once every thousand years, and probably less often.**

The portion of the star closest to the center of the black hole would experience a stronger gravitational pull than the most distant region. This tidal force would stretch and elongate the star, eventually ripping it apart. Theoretical modeling of such encounters indicates that the black hole would capture a significant portion of the disrupted star and form a disk of matter — called an accretion disk — that would eventually fall back into the hole. The tidal forces would accelerate the remainder of the star enough for the material to reach escape velocity and be ejected from the environs of the black hole.

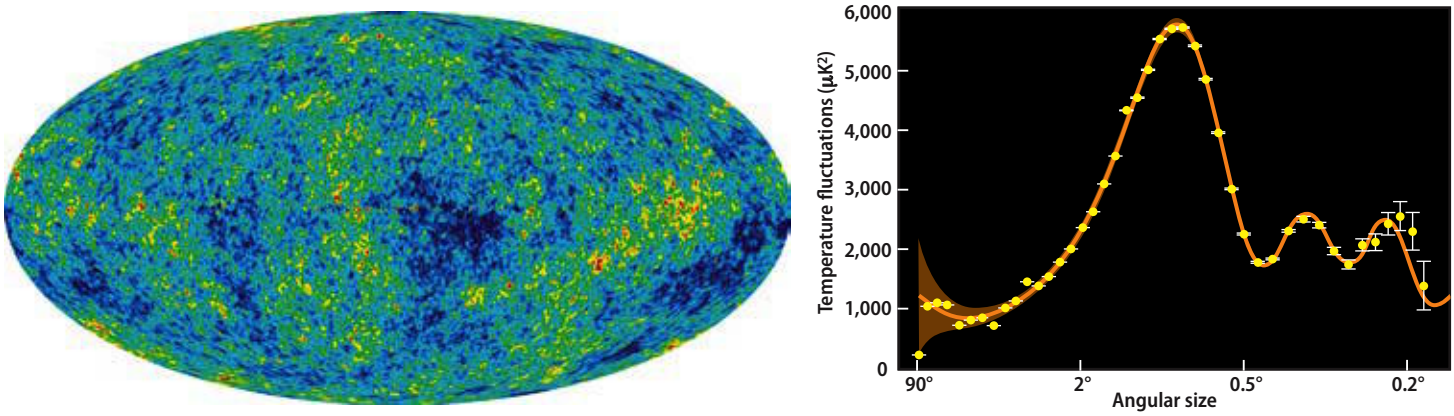
The accretion disk that falls back in would produce a luminous flare in much the same way that continuously feeding black holes do. But there's only a limited supply of matter. At its brightest, the flare could outshine the Sun by 100 billion times, but vast amounts of interstellar dust would hide the galactic center and greatly diminish the optical signal. **We probably wouldn't see anything with our eyes. However, it is likely that in other, less obstructed wave bands — such as infrared and X-ray — we would see a dramatic brightening.** Such a disruption event can "give away" a dormant supermassive black hole. Thus, astronomers are trying to find such flares in distant galaxies to expose black holes in hiding. **— Tod Strohmayer,** NASA's Goddard Space Flight Center, Greenbelt, Maryland

ASTRONOMICAL HISTORY

Q: When did observers determine that "wandering stars" were not stars at all, but rather planets? — Lyle Schroeder, Milwaukee

A: Ancient skywatchers didn't consider Earth a planet. So the wandering stars also didn't fall into this category. But they did count the five visible planets as something special and different from the "fixed" stars because of their motions.

When Galileo and others turned early telescopes on these wandering objects starting in 1610, they weren't sure what they saw. The fixed stars appeared as points of light while the



The fluctuations of the cosmic microwave background (CMB) are the imprint of structure in the early universe. The angular sizes (shown in the plot on the right) of the fluctuations tell cosmologists about the amount of dark matter, dark energy, and ordinary matter in the universe. CMB map: NASA/WMAP Science Team; Data plot: *Astronomy*: Roen Kelly after NASA/WMAP Science Team

planets were visible as disks. Galileo found that Jupiter had moons of its own, but he could not resolve features on the disk or determine the planet's rotation. In fact, Galileo drew a circle for Jupiter only as a reference to the motion of its moons.

The next big break came from Christiaan Huygens' 1659 *Systema Saturnium*. He described Saturn and its rings in detail. Huygens also included a drawing of Jupiter showing two equatorial cloud bands. In 1664, astronomer Robert Hooke published his findings on the rotation of Jupiter based on observations of the Great Red Spot.

As telescopes improved, observers saw more detail on planetary bodies, while the fixed stars remained points of light. Discovering the true nature of the planets has been a long, and at times confused, process. — **Raymond Shubinski,** Contributing Editor

COSMIC CHARACTERISTICS

Q: How do scientists measure dark matter, dark energy, and normal matter using the CMB? — Tom Clune, Baltimore

A: The early universe was so hot that matter and radiation acted as a fluid. Ordinary matter was ionized, and radiation and electrons were tightly coupled — meaning they constantly collided and scattered off each other. Dark matter doesn't interact with radiation, so it didn't move with the electron-radiation fluid.

Find out the difference between astronomy and cosmology at www.Astronomy.com/toc.

Tiny fluctuations in the dark matter density meant that this electron-radiation fluid could fall into these gravitational wells. This set up a tug of war between varying pressures within the fluid, which was making it expand, and gravity, which was making it collapse — in short, a sound wave!

As the universe expanded, it cooled. Eventually, the electrons decoupled from the radiation and joined with nuclei to form neutral atoms. This process, called "recombination," released the radiation, which traveled to us essentially unhindered. We see the sound wave projected onto the sky, frozen at the time when the universe became neutral.

The universe's expansion has redshifted the radiation into the microwave band, and we call it the cosmic microwave background (CMB). The CMB sky is almost uniform with an average temperature of 2.73 kelvins, but contains small fluctuations (about 1 in 100,000) hotter and colder than this average. **The data plot shows the power in these temperature fluctuations as a function of angular separation of points in the sky.** In this plot, the CMB looks like a series of peaks and troughs of unequal height, with a plateau at the largest scales. **The shape of this graph tells a lot about the amount of dark matter, dark energy, and ordinary matter in the universe.**

In a simplified picture, dark matter changes the height of the first peak relative to the plateau at the largest scales. Dark energy changes angular separation corresponding to the peaks. Ordinary matter changes the relative heights between odd and even peaks. However, we need a measurement of the expansion rate at the present time to cleanly separate the effects of dark matter, dark energy, and ordinary matter in the CMB. — **Hiranya Peiris,** University College London

FROZEN OPTICS

Q: Is it normal for telescope optics to freeze up when the temperature is below freezing with high humidity? If so, how can I prevent this? — William Jones, Naperville, Illinois

A: Dew forming on optics is the bane of many amateur astronomers. Dew coats optics early in the evening when the temperature is above freezing. Later, if the temperature dips, the dew freezes.

The best way to avoid dew — or ice — on optics is to use a dew heater, which several manufacturers offer. Such a device (usually a heat coil connected to a battery) raises the optics' temperature just above the dew point to prevent moisture deposits. If your dark site has an extreme dew problem, you can buy heaters for objectives, secondary mirrors, and even eyepieces. — **Michael E. Bakich,** Senior Editor

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Imaging prehistoric sunrises

With a bit of detective work and graphic manipulation, this astrophotographer visualizes sunrises that prehistoric skywatchers saw. **text and images by Frank Zullo**

A small group of petroglyphs sits near the bottom of the Mormon Trail at South Mountain Park in Phoenix. Most prominent among this assemblage of prehistoric Hohokam rock art is a pair of lizard figures with arms upraised as if to greet the Sun. City of Phoenix Archeologist Todd Bostwick calls it the "Lizard Site" in his book written with Peter Krocek, *Landscape of the Spirits*. He includes the Lizard Site as a location that may have been used to observe sunrise on the summer solstice.

So, on the June solstice in 2005, I found myself standing with the lizards, waiting for the Sun to rise. On a previous outing, I had checked the compass heading of the solstice sunrise, and I found that it pointed straight at Four Peaks. This notched landmark of the Mazatzal Mountains lies 45 miles (72 kilometers) east-northeast from the Lizard Site. How fitting it would be if the solstice Sun rose right in the center of these sacred peaks.

The lizards and I continued to watch the sky brighten. All of a sudden the first flash of sunlight burst over the horizon. Bull's-eye! I saw the brilliant summer beacon centered in the sights of the mountain. Historians agree that past cultures marked solstices and equinoxes for ceremonial purposes, and the Hohokam left many such calendar sites. It seems difficult to believe they wouldn't have used this spot for exactly that purpose.

Imaging the site

Of course, few things are ever that simple. Sunrise and sunset points shift slightly over time due to a 2.5° change in the tilt of Earth's axis that occurs during a 41,000-year period. Currently, the axial tilt, called the obliquity of the ecliptic, is decreasing. This causes solstice sunrises and sunsets to appear closer to those at the equinoxes. If I were determining what those prehistoric sunrises looked like — and possibly how the Hohokam used the Lizard Site — I would have to come up with a way to visualize the effect of this solar shift.

I returned to the site on the 2006 summer solstice with my Nikon D2X digital camera, a sturdy tripod, and a 105mm focal length lens to shoot some same-scale images. The first was a silhouette of Four Peaks taken in bright morning twilight. Then I captured one image of the Sun in mid-rise, and another just after it cleared the horizon. The second showed the solar disk oblated due to atmospheric refraction. For both images I placed a Kodak 4.0 neutral-density gelatin filter over the lens to reduce the Sun's brightness. I slightly underexposed the sky above Four Peaks and the images of the Sun to guard against distortion of critical bright edges.

The author's Sunrise Simulator depicts the summer solstice sunrise from A.D. 1009. This view includes the graphics he created for functionality. The ruler's smallest increments represent 2'. The rise line on the right is the one from the 2006 solstice. He uses the left line as a baseline to calculate shifts.

Developing a simulator

From these captured scenes, I began compiling a multilayered *Photoshop* image I call the "Sunrise Simulator." I used the view of Four Peaks as the background and copied the full Sun image to a separate *Photoshop* layer. Changing the blending mode of that layer to "screen" eliminated the black sky and rendered the solar disk brighter wherever it overlapped the background sky. It was like magic seeing a moveable, realistic Sun floating over Four Peaks. I couldn't help but play with it a while, discovering how the Sun fit with the horizon and peeked out of numerous crannies.

To keep on track, I added a sunrise path while raising and lowering the Sun. For this, *SkyMap Pro 10*, the astronomy program by Chris Marriott, proved invaluable. I copied a screen image that included the declination line passing closest to the azimuth of the solstice sunrise. With this line as a guide, I drew a "rise line" on a separate layer of the simulator image. In the future, I may use a star-trail photo aligned with the background landscape to get an exact rise line.

For measuring solar shift, I decided on a ruler of 2-arcminute (2') increments. Using the same camera and lens, I photographed a pair of lines 1.5 inches (3.8 centimeters) apart at a distance of 214 feet, 10 inches (65.5 meters). That odd solution came from the need to shoot

The Sun rises on the 2006 summer solstice from a location archeologist Todd Bostwick dubbed the "Lizard Site" at South Mountain Park in Phoenix. The first point of sunlight peeking out of the middle notch of Four Peaks is what we see on the solstice today. This is the view the prehistoric Hohokam would have seen a thousand years ago, 8 days before the solstice.

These four Sunrise Simulator views depict the Sun's 4-year shift due to our year being slightly longer than 365 days. It shows how ancient observers would have seen the first peek of sunlight 8 days before the summer solstice for the years A.D. 1008 through A.D. 1011.

This sunrise sequence depicted by the Sunrise Simulator is the same as the one above, but here the author shows the Sun's position at the same altitude instead of at its rising points. He did this to emphasize the Sun's shift instead of just illustrating the point of sunrise.

with the lens at infinity to guard against any optical shift in scale and to keep the target at a distance appropriate for maintaining acceptable focus. I opened the resulting image in *Photoshop* and used it as a template to make a pair of correctly spaced lines, which I duplicated several times to build the ruler layer.

The last order of business was to set the rise path of the 2006 summer solstice Sun. I would use that as a baseline from which to figure all solar shifts. Here's where I used the image of the partially risen Sun. I copied it to a separate layer and aligned its horizon to that of the background. Then I aligned the full Sun with the partial Sun and the rise path to a center point I had placed on the full Sun.

Looking back in time

The simulator was ready to go. I decided to set the time machine for the summer solstice of A.D. 1009, which would allow me to travel a millennium into the past. *SkyMap Pro 10* calculated the time of solstice as June 16 at 7:19 A.M. in the Mountain time zone. The program also reported a 5:16 A.M. sunrise at azimuth 60°46'15". I subtracted that from the simulator's baseline rise path azimuth of 60°55'37" to get a shift of 9'22". I keep arcseconds in the calculation simply to determine if the result is closer to a full or half arcminute. All I had to do then was shift a duplicated rise line 9.5' north of the baseline, center the Sun on this prehistoric solar track, and position it to just peek over the horizon. And there it was: a simulated view of the 1009 summer solstice sunrise.

I quickly noted the twin-beamed nature of the event. However, this came from viewing it enlarged under ideal conditions. Could the eye actually detect those two closely spaced points of light while watching the actual sunrise? That is a question I hope to answer at the next solstice. It won't be easy because the Sun no longer reaches that far north. I can't get the Sun to move, so I will have to simulate the shift by moving my vantage point 9.5', which in this case is 648 feet (197.5m) toward the azimuth of 331° (to the north-northwest).

If I can visually confirm that this prehistoric sunrise appeared as two points of light blending into one, it might explain the pair of lizard petroglyphs marking the location. The joined twosome seems to be male and female, with the larger

This multi-pointed sunrise is a photograph that's almost identical to the third panels of each of the 4-panel Sunrise Simulator views in this story. This is the same view ancient observers at the Lizard Site would have seen 8 days before the summer solstice in A.D. 1010. The author took this image 2 days after the 2006 summer solstice from a position slightly down the trail from the Lizard Site.

Frank Zullo *is a professional photographer and seasoned skywatcher who is well-known for his nighttime landscapes of the Southwest.*

male holding the arm of the female. On her abdomen is a pair of concentric circles. A circle inside another circle sometimes symbolizes the Sun and the Moon, which many cultures consider opposites (day and night, male and female, etc.). Concentric circles also can represent a portal to other levels of being. A portal as part of a woman's body could signify the womb through which new life comes from the joining of opposites. Symbolizing these concepts could have made this a meaningful ceremonial sunrise.

Searching other dates

The Lizard Site might also have served as a calendar that displayed a distinctive sunrise several days before the solstice. This would be of practical use to village elders or priests who could use the information to determine the correct timing of upcoming ceremonies and to begin preparations. Evidence suggests that the number 4, and multiples of it, had spiritual significance in such matters.

Wes Holden, the retired director of Arizona Highways book division and longtime student of rock art, found such evidence at another South Mountain location. His extensive examination of the rock art panel at the "Sun-Struck Site" uncovered convincing interactions of light and shadow with petroglyphs that mark solstices, equinoxes, and most cross-quarter days. Some of these interactions preceded the actual events by 4, 8, and 12 days.

So I decided to go back to my Sunrise Simulator and search the year 1009 for one of those pre-solstice marks. At 4 days from the solstice, I found that the Sun moves too little to delineate any useful interactions. However, I found a workable situation at 8 days prior. That was the first day the Sun would have risen into the middle notch of Four Peaks.

I expanded my Sunrise Simulator search backward and forward in time examining small blocks of roughly 30-year increments. My results showed the 8-day mark to work reliably for most of the 10th through 12th centuries.

Complicating the use of any solar-sighting calendar is the 4-year cycle of sunrise shifts caused by the fractional length of the year. The Sun takes about 365.2422 days to travel from one solstice to the next, but the calendar allows it only 365 days. This results in the Sun falling behind by about 6 hours each year.

For a Hohokam observer watching the 8-day interaction, a smaller portion of Sun would rise into the notch each year until finally falling short of the mark. That was the year the Sun-watcher would unknowingly have to wait an extra day as the Sun jumped ahead and rose well into the notch to restart the cycle. Fortunately, this complication would have caused no observational problems.

Future studies, other sites

I'm not sure what pleased me more — finding strong evidence about the nature of the Lizard Site or inventing a useful tool for examining such sites. Maybe I answered that by having already made four more simulators keyed to other sites.

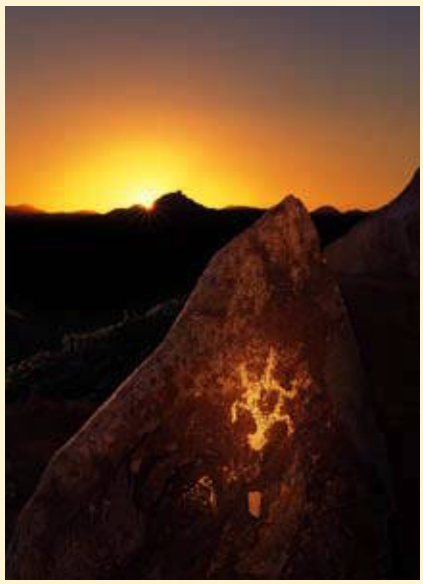
The most interesting one is a winter solstice sunset viewed from a location marked by a solitary lizard petroglyph a few miles from the Lizard Site. My studies include a perceptibly larger winter Sun, a different path of motion, a higher horizon, and a slightly less-stretched-out solar disk — all neatly figured by the Sunrise Simulator. I can't wait to stand at that site and re-create observations made by skygazers a millennium ago.

Other projects are in the works

Besides my studies at the Lizard Site, I have made four more Sunrise Simulators keyed to other historical sites. I've dubbed the most interesting one the "Lizard Monolith Site." From there — about 4 miles (6.4 km) from the Lizard Site — an observer can see a winter solstice sunset from a location marked by a solitary lizard petroglyph.

My studies show differences from the Lizard Site: a perceptibly larger winter Sun, a different path of motion, a higher horizon, and a slightly less-stretched-out solar disk. Although at the Lizard Monolith Site the Sun has shifted 10' from 1,000 years ago, it still would have set in the same notch at that time.

On the other side of the monolith rock with the lizard petroglyph, there is a natural bench perfect for sitting and viewing the sunset. Two separate views were taken to deal with the extreme contrast. They were later assembled in *Photoshop*. The lizard petroglyph was illuminated by a flashlight. — *F. Z.*



The winter solstice Sun sets in a distinct notch of the Sierra Estrella Mountains as seen from the Lizard Monolith Site at South Mountain Park in Phoenix.

One summer solstice interaction occurs at a location called the "Sun-Struck Site." At this South Mountain Park rock-art site, a notch in the shadow of an overhanging rock aligns with a pictured star on the summer solstice. At the same time, the right edge of the shadow also bisects concentric circles. Many other alignments occur at this Hohokam petroglyph site on the solstices, equinoxes, and cross-quarter days.

Meade's LightSwitch technology makes observing a snap

This new go-to scope takes the hassle out of setup and offers high-quality optics to boot. **by Phil Harrington**

Meade's 6-inch f/10 ETX-LS is one of the most exciting telescopes to come along in recent years thanks to "LightSwitch" technology, which offers hands-off initialization. The telescope is the first to combine GPS technology with a built-in, wide-field digital camera to let the scope synchronize to the sky automatically. It even talks to you as it goes.

Recently, I had a chance to put an ETX-LS through its paces. Our test telescope came with Advanced Coma-Free (ACF) optics, but Meade also offers a less expensive unit with Schmidt-Cassegrain optics. The ACF version uses a matching mirror and a corrector plate to deliver sharper images across the full field of view. Both scopes, however, come standard with Ultra-High Transmission Coatings (UHTC) for improved image brightness and contrast.

Setup and initialization

The telescope arrived in two boxes. The smaller container housed the adjustable tripod. The larger one included the telescope/mount combination, a 26mm Super Plössl eyepiece, a red-dot finder, and the AutoStar III handcontroller and cable. The box also included the instruction manual, a printed Quick Start Guide, and a CD-ROM containing Meade's *AutoStar Suite*.

To set up the tripod, I slid the plastic spreader tray onto the rod that

At the tube's bottom, you'll find Meade's Electronically Controlled Locate Identify Position System (ECLIPS) wide-field CCD imager. It's crucial in helping the telescope align to the sky.

Meade's 6-inch ETX-LS features the company's LightSwitch technology, which aligns the telescope's drive with the flip of one switch. Equipment photos: *Astronomy*: James Forbes

Specifications

ETX-LS

Optical design: Advanced Coma-Free (ACF) or Schmidt-Cassegrain (SC)
Aperture: 6 inches
Focal length: 1,524 millimeters
Focal ratio: f/10
Tripod: Adjustable height with steel legs
Controller: AutoStar III
Power: 8 C-cell batteries or AC adapter
Price: $1,399 (ETX-LS ACF); $1,299 (ETX-LS SC)

extends under the tripod's mounting plate. I threaded on the large thumb knob, but had to be careful not to overtighten it because too much force could crack the tray.

The top of the tripod's mounting plate has a central protrusion and three thumb knobs for attaching the telescope base. I lifted the telescope using the handle built into the mounting arm and placed it on the tripod. The plate's self-centering design lined up the spring-loaded mounting bolts.

First test: self-alignment

After setup, I flipped on the LightSwitch and let the telescope do its thing. Unlike most other go-to drives, the ETX-LS does not have any axis locks. Instead, friction holds it firmly in place. That eliminates the need to tighten levers, but it also prevents you from using the scope manually if the batteries die.

Although you can power the ETX-LS with eight C-cell batteries, I used a 12-volt rechargeable battery instead. If you use one with this scope, you will need a DC power cord (not included). Meade's #607 cord is suitable, as are various cords from other suppliers.

As the built-in speaker announces, the initial alignment begins with the telescope finding "North and Level" and establishing a GPS connection. To speed things along, you can enter your observing site's location and the time manually.

Once set, the ETX-LS slews to the first alignment star. Meade's Electronically Controlled Locate Identify Position System (ECLIPS) wide-field CCD imager, positioned on the tube bottom, takes an image of the sky and analyzes it for the star's position. The scope then moves to another self-selected alignment star and repeats the process.

If the ETX-LS's ECLIPS detects both stars, the telescope announces that it is ready to use. If not, perhaps because a house or tree obscured one star, it repeats the procedure with other stars until alignment is successful. From my experience, the alignment process takes an average of 9.5 minutes.

Second test: observing

My first target was Jupiter. As the telescope dutifully moved in on its target, the onboard narration, voiced by Sandy Wood from McDonald Observatory's long-running radio program *StarDate*, told me about the planet. Peering through the 26mm eyepiece, the planet sat just slightly west of center. Switching to a 10mm eyepiece, the ETX-LS displayed a detailed array of Jupiter's belts.

I then selected open cluster M52 in Cassiopeia, which was rising in the northeast. Although the telescope had to move a quarter of the way around the sky, the cluster was within the 26mm eyepiece's field when it stopped. The cluster's stars appeared sharp across the full field, even through a 5mm eyepiece.

My next target was globular cluster M3 in Canes Venatici, which was low in the northwest. After another 90° slew, the telescope revealed a compact, resolved ball of stardust, while Wood simultaneously explained what globular clusters are. You can mute the narration by pressing the controller's "Media" button.

As I continued to observe, each target I selected lay somewhere in the 26mm eyepiece's field of view. Even when I tried to throw it a curveball, such as selecting Vega (Alpha [α] Lyrae) when the star was at the zenith (the overhead point), the AutoStar performed well.

In addition to helping the telescope initialize, the ECLIPS camera can take wide-field images you can view on an attached monitor or save on a mini-SD card. The digital camera cannot take photos through the scope, however. You'll need a separate camera for that.

The ETX-LS is an exciting telescope. The optics are sharp, the aiming is accurate, and the narrations prove informative. Meade has produced a multimedia instrument that should really open up the universe, especially for newcomers to our hobby.

The accessory panel of the ETX-LS offers audio and video outputs, a focuser control, and two USB ports.

Contact information

Meade Instruments Corp.
6001 Oak Canyon
Irvine, California 92618
[t] 800.626.3233
[w] www.meade.com

The ETX-LS comes in two optical configurations. A user can order either Meade's Advanced Coma-Free or Schmidt-Cassegrain design.

Contributing Editor **Phil Harrington** *is the author of the equipment guide* Star Ware *(Wiley, 2007).*

Observing Basics

by Glenn Chaple

LOL astronomy

A little cosmic humor can get you through those cloudy nights.

Question: A football player gets athlete's foot. What does an astronaut get? Answer: Missiletoe!

I admit that joke is an old saw, and you may doubt the value of an article on astronomy jokes and cartoons. But trust me — a sense of humor is just as important to the amateur astronomer as the latest wide-field eyepiece.

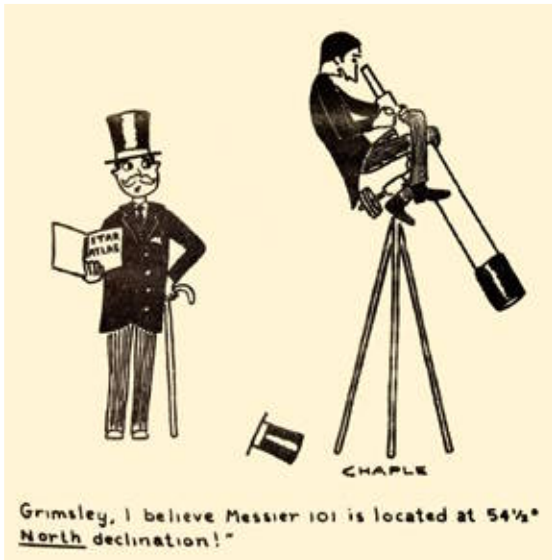
Some years ago, I received a letter from someone amused at the term *serious astronomer*. In his mind, the phrase conjured up an image of some mirthless individual frowning while squinting into the eyepiece. If you're a frowner or a squinter, lighten up, my friend!

Amateur astronomy can be a frustrating hobby. We swat mosquitoes in the summer and battle frostbite in the winter. Eyepieces fog up, counterweights come loose and land on our toes, bats poop on our telescopes (honest, it happened to a friend — down the tube and *splat!* on a newly coated mirror). Yes, sir, if you can't laugh and shrug off your misfortunes, you'll either wind up in a straitjacket or in the cardiac ward.

Let's say it's cloudy, and you can't go out tonight. Instead of wailing and beating your chest, take a deep breath and stroll over to your computer. Pay a visit to frequent *Astronomy* astroimager Anthony Ayiomamitis' astronomy humor page at http://www.perseus.gr/Astro-Jokes.html.

Anthony has collected a veritable galaxy of astronomy jokes and anecdotes. You'll chuckle at gems like "The Twelve Commandments for Amateur Astronomers," "Murphy's Laws for Astronomers," and "Astronomical Bumper Stickers."

Browse the "Observing Basics" archive at www.Astronomy.com/Chaple.



If you laugh so much your sides start to ache, move on to the "Top Ten Technical Errors/Anachronisms in the Movie *Apollo 13*." It's amazing how such a finely crafted movie can still contain subtle mistakes. When you're ready to return to astronomical humor, check out "You know you're a Deep Sky person when … " If you're a child of the 1950s or 1960s (or older), read Anthony's "Top 5 signs an amateur astronomer is getting old." Funny, but true!

Want more laughs? Log on to Andy Blackburn's Astronomy Humor Page (http://home.g-net.net/~andy/astrohum.htm). "You Might NOT Be An Astronomer If You Think That … " and "You Know You Are a Redneck Astronomer If … " will entertain Jeff Foxworthy fans. Think you're the only person on the planet who's been the victim of astronomical adversity? Andy's list of "Astronomy Bloopers" will serve as a gentle reminder that you're not alone.

If you prefer visual humor, you'll be glad to know the Internet teems with astronomy-related cartoons. You may not have heard of Sidney Harris, but you've seen his science cartoons in numerous publications. You'll find a gallery of his astronomy cartoons at http://www.sciencecartoonsplus.com/gallery/astronomy/index.php.

For more samples of cartoons that deal with astronomy and space science, stop off at Mark Parisi's page (http://offthemark.com/search-results/key/astronomy) as well as Theresa McCracken's (http://www.mchumor.com/science_space_cartoons.html). An evening spent with the wit and humor of this trio of cartoonists will help ease the pain you've felt since the night you dropped an expensive eyepiece and stepped on it in the dark.

If you're beset with a period of inclement weather, curl up with a copy of Ken Fulton's *The Light-Hearted Astronomer* (no longer in print, but available on outlets like Amazon.com). Published in 1984 but still relevant today, it's a humor-laden guide for the novice backyard astronomer that veterans will also enjoy.

Fulton hits the nail on the head when he asserts, "If — God forbid! — you are devoid of a sense of humor and feel that the distinguished science of astronomy has no place for rib-tickling in its hallowed halls, you'd better stop reading right here and check out someone's doctoral thesis instead." My tip: Lose the thesis and read *The Light-Hearted Astronomer*. You'll laugh and learn at the same time.

To close out my spiel on astronomy humor, permit me to share a cartoon I drew for the September 1980 issue of *Deep Sky Monthly*. I hope it's better than my missiletoe joke!

Questions, comments, or suggestions for more astronomy humor? E-mail me at gchaple@hotmail.com. Next month: the universe in a nutshell. Clear skies!

Evening Stars

by David H. Levy

A permanent IYA

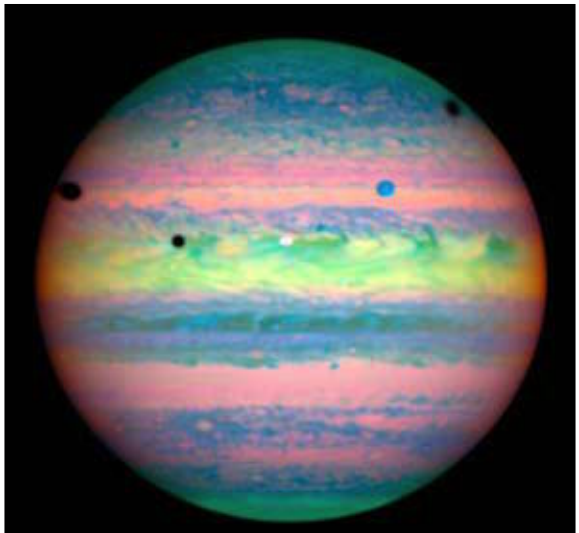
The International Year of Astronomy may be over, but that doesn't mean we should stop gazing at the sky.

On December 31, 2009, the International Year of Astronomy (IYA) came to a close. Although IYA-related events still occurred in January 2010, the celebration's major goal, to inspire the world to look up at the sky, ended with the turn of the calendar.

However, I suggest that the work of the IYA continue indefinitely. Historically, the culmination of the events of 1609 spilled into 1610, when, on the evening of January 7, Galileo Galilei turned his telescope toward Jupiter. (It was high in the constellation of Taurus, not far from bright red Aldebaran and just north of the almost-Full Moon.) The telescope's narrow field of view made it difficult to find Jupiter, but when Galileo did, he saw a retinue of three "stars," one to the right of the planet and two more to its left.

In Galileo's own words: "On the seventh day of January in this present year 1610, at the first hour of night, when I was viewing the heavenly bodies with a telescope, Jupiter presented itself to me. … [I saw] that beside the planet there were three starlets, small indeed, but very bright. Though I believed them to be among the host of fixed stars, they aroused my curiosity somewhat by appearing to lie in an exact straight line parallel to the ecliptic, and by their being more splendid than others of their size."

With these words, Galileo reported one of the most astonishing discoveries in human history. The four moons of Jupiter he eventually discovered would change the course of astronomy. Four hundred years later, humanity commemorated this event by officially closing the IYA. But Galileo's discovery was a beginning, not an end, and 400 years later it reminds us not of our past accomplishments, but how much work remains.



The Galilean moons, named after their discoverer Galileo Galilei, provide visual proof of the complexity and beauty of the heavens. In this infrared image by the Hubble Space Telescope, two of the four moons are visible (Io, the white circle near the center, and Ganymede, the blue circle in the upper right), along with three of the moons' shadows (Ganymede's, Io's, and Callisto's, from left to right). NASA/ESA/E. Karkoschka (University of Arizona)

What's next? As part of our personal IYA project, my wife, Wendee, and I have been collecting the signatures of those who looked at the sky sometime during the IYA (not just those who have looked through a telescope). With more than 2,100 signatures from 2009, we plan to continue that effort well into 2010. But, more importantly, we still have much work to do. That's what IYA was truly about: inspiring people to go out and look at the night sky.

Each signature is a statement of purpose and commitment. "I have looked up at the sky," the signer declares, "and enjoyed the experience enough that I want to look up again and again." That is all it takes. No expensive optics necessary, just a little bit of perseverance and an inquiring mind.

And what did I see when I last looked up? I saw the stars in their subtle — but noticeable — movement through the sky. That almost undetectable motion teaches us an important thing: Each night brings its own miracles. We can take this for granted, but it is all part of the wonderful show that begins every evening with the onset of twilight. That's why I hope the spirit of the IYA continues past 2009.

And if you use a telescope to look up, even more discoveries await. Saturn's mighty rings are incredible. Looking at a picture of the ringed planet is one thing, but personally seeing those bright rings through a telescope is quite another. And during the IYA's end, Saturn's multiple rings and dozens of moons had an added attraction: the presence of Cassini, a spacecraft taking amazing pictures of the Saturn system as it orbits the Sun.

Right next door, Jupiter's moons offer another "wow" moment. Just as Galileo did 400 years ago, we can notice the moons moving in relatively little time. In fact, with Io hurtling around Jupiter in less than 2 days, the moons' positions can change noticeably even on the same night.

Galileo saw these moons and marveled, but he didn't stop observing until he went blind, almost 30 years later. We shouldn't stop looking either, even though the IYA has officially come to a close.

So go out and enjoy the moons of Jupiter, as Galileo did, or the other wonders of the night sky, as more than 2,100 signers have. Rejoice in the starry night sky for years to come!

Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

Secret Sky

by Stephen James O'Meara

Deep naked-eye diving

See if you can spot objects millions of light-years away with your eyes alone.

In the November 2009 issue of *Astronomy*, I challenged observers to detect three naked-eye galaxies: Messier 31 (M31) in Andromeda, M33 in Triangulum, and NGC 253 in Sculptor. These island universes lie 2.9, 3.0, and 10.0 million light-years distant, respectively.

Now I'm asking naked-eye observers in the Northern and Southern Hemispheres to plunge into the deep end of the celestial pool. I'd like you to push your vision to the very limit and look for three more galaxies without optical aid: M81 in Ursa Major (11.9 million light-years distant), NGC 5128 in Centaurus (12.9 million light-years from us), and M83 in Hydra (14.9 million light-years away).

Based on my visual estimates, NGC 5128 shines at magnitude 6.6, M81 at magnitude 6.9, and M83 at magnitude 7.5. As seen from mid-northern latitudes, M81 sails high in the north after evening twilight throughout the spring. As seen from mid-southern latitudes, M83 and NGC 5128 are highest in the south around midnight in mid-April, and around 9 P.M. June 1. This month's challenge is a triple dare for those observing from low northern or southern latitudes, where all three objects climb reasonably high.

Breathe deep

Extremely dark and transparent skies are required for success. To avoid neck and eye strain, lie in a comfortable position. You'll also need to keep warm and stay relaxed (soothing music may help). Plan to observe for at least 30 minutes or more for each object. And be patient. It takes time to confirm and reconfirm individual photon hits from these dim and distant objects.

M81 in Ursa Major lies some 12 million light-years away, but is still faintly visible to the naked eye. The author estimates its magnitude at 6.9, and from mid-northern latitudes M81 sits high in the north during evening hours this time of year. N.A. Sharp (NOAO/AURA/NSF)

To find your target, start with the brightest naked-eye star in the region, then progress to fainter ones as you hop to the galaxy's location. Once there, lie back and take several deep breaths — like you're about to dive deep into water — then start your search. But unlike with diving, don't hold your breath! Breathe regularly and naturally as you look, averting your gaze while focusing your attention on the galaxy's position.

Don't stare too long. The longer you look (and the less you breathe), the darker the view becomes, owing to oxygen depletion and other physiological factors. Take several short "dives" of about 20 seconds each. Relax for a few minutes between searches. It also helps to gently sway your head back and forth so the target sweeps across the long axis of your eye. The eye is an efficient motion detector, and the sweeping motion continuously stimulates the eye's low-light-level receptors.

After a few minutes of observing, get up and walk around; maybe jump up and down a few times to replenish the flow of oxygen to your eyes.

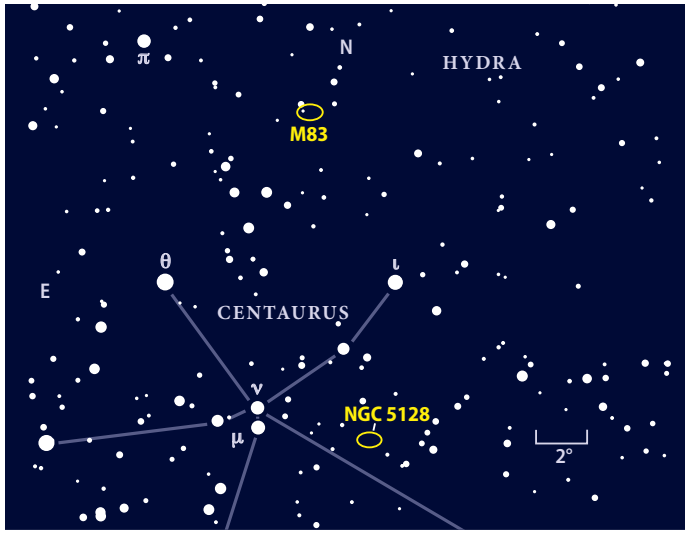
The view

Don't expect to see your target consistently. Most likely, it will swim in and out of view, appearing as tiny intermittent puffs of faint light coming from the same point in space. Remember, you're pushing the visual envelope, and you're trying to catch photons swimming through an unstable atmosphere.

Expert naked-eye observer Becky Ramotowski of Tijeras, New Mexico, has seen M81 on several occasions. "It's okay to cheat a bit with binoculars first to get a firm imprint of where the galaxy is located," she says.

Ramotowski doesn't go directly to the naked-eye target first, but takes time to view a few easy objects before diving

M81 in Ursa Major lies 11.9 million light-years distant, at a magnitude of about 6.9, making it barely visible to naked eyes high in the north from mid-northern latitudes. *Astronomy*: Roen Kelly



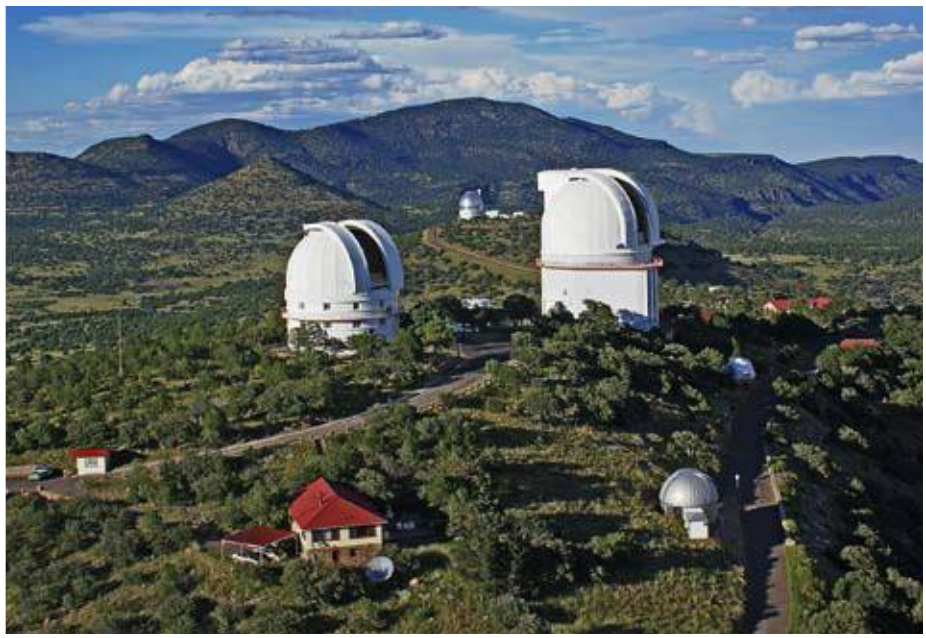
NGC 5128 in Centaurus and M83 in Hydra, both over 12 million light-years away, have magnitudes of about 6.6 and 7.5; they're visible high in the south from mid-southern latitudes. *Astronomy*: Roen Kelly

into the deep. "Do some eye warm-ups, so to speak," she says. She also memorizes star fields in patterns of triangles or right angles, which helps her "hop" to the galaxy. "It takes some time," she cautions, "but on pristine nights, when everything comes into place, I can usually bag my target."

Brent Archinal, who lives near Flagstaff, Arizona, has also spied M81 without optical aid; he gives a wonderful account of his experience in the May 1997 issue of *Astronomy* (pages 20–24). He also told me about a couple of brothers who were "out observing for one of the first times with their telescope and couldn't find M81 through the finder, so they just pointed it at the nebulous spot they were seeing with their naked eyes, and there it was! Now there are some good and unbiased eyes!"

While doing some binocular observing in January 1997, Brian Skiff saw M81 "quite convincingly naked-eye" from the catwalk of the Lowell Observatory's 1.1-meter telescope on Anderson Mesa in Arizona. And Barbara Wilson of Houston first saw M81 naked-eye in 1987 at the Texas Star Party. "After an early evening rain for about an hour," Wilson says, "the sky cleared to an amazing clarity. M81 was visible with averted vision probably 50 percent of the time."

NGC 5128 is 0.3 magnitude brighter than M81, but it's a grass-grazer from the southern continental United States. I've succeeded from Hawaii, and Australian amateur astronomer Darren Wong spied it under the dark and transparent skies of Leyburn in Queensland. "Yep," Wong says, "the skies were that good!"



Damond Benningfield

McDonald Observatory, in southwest Texas, looms over the site of the Texas Star Party. During the event, running May 9 to 16, all three of this month's deep-sky, naked-eye targets will be visible at once.

From near Mudgee, New South Wales, Australia, Archinal nabbed M83 "with great difficulty and concentration." He says the real problem with seeing M83 is not the galaxy's faintness, but its proximity to a 7th-magnitude star only 20' to its east. Nabbing M83, then, becomes a challenge in resolution: Not only does the atmosphere have to be dark and transparent, but it also must be exceptionally stable. Under such conditions, I actually found M83's proximity to that 7th-magnitude star helpful when I spotted it from Hawaii; the star directed my eye to the galaxy's exact location. Otherwise, I might not have seen such a dim dust mote of light.

Extremely dark skies are hard to find these days. Still, I'd love to hear from anyone who succeeds, or has succeeded in the past, with observations of these deep-sky denizens. Send your reports to me at someara@interpac.net.

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

Kevin **Nelson**

Co-founder and Vice President of Sales and Marketing, Quantum Scientific Imaging

Kevin Nelson, co-founder of Quantum Scientific Imaging, sees himself as more of a sailor than a scientist. courtesy Kevin Nelson

"I've always been interested in understanding the universe," Kevin Nelson says, sounding like the typical scientist and "technology evangelist." But despite taking astronomy classes while pursuing his computer science degree, he didn't love it yet. "I'd never been especially interested in visual astronomy, and back in the early 1980s I found film-based astrophotography to be among the most frustrating things I've ever done."

It's no wonder, then, that he considers himself more a sailor than a scientist (even though he sails only part time), because it was celestial navigation that brought him back to astronomy. "I'm a bit of a history geek and wanted to learn more about how sailors navigated the globe, before Global Positioning Systems," he says. When he subsequently discovered what today's small telescopes and cooled CCD cameras could do, it reinvigorated his interest in astronomy. "I was absolutely hooked."

Nelson has lived in Southern California almost all his life. Today, he enjoys sharing the challenges of imaging the night sky with his two boys, both of whom have developed a keen interest in astronomy. And, whenever he can, he still enjoys sailing. "I'm not sailing today as much as I would like," he says, "but I still get out day-sailing occasionally, and do at least one longer sailing trip per year."

What's something cool about Quantum Scientific Imaging (QSI) that nobody else knows?

I'll tell you two things. First, Neal Barry (the CEO of QSI) and I have been friends and business partners for years. He's an avid amateur astronomer and our chief camera designer. Neal began applying his professional CCD camera design experience to custom cameras for astrophotography more than a decade ago. The QSI 500 Series cameras exist because that's the type of camera he always wanted to use for his own work.

Second, the largest single market for QSI is medical imaging, where our cameras play a part in applications such as drug discovery and diagnosing human diseases. The range of applications for scientific cameras today is truly astounding and growing all the time.

How has QSI changed through the years?

The biggest change is volume. We launched the QSI 500 Series initially for the astronomy market because we knew astronomers would appreciate the low noise, compact size, and build quality of QSI cameras — but we also knew that it would take a while for astronomers to trust a new company.

The popularity of the 583 has brought us an acceptance in the market that is quite gratifying. It's fun to attend imaging events nowadays and let current QSI camera owners "sell" our cameras to potential new customers for us.

"Astronomy is really the last major area of study where a dedicated amateur can make a real contribution to science."

What are some of your most popular products?

In February 2009, we introduced the 8.3-megapixel ASI 583 family. Sales of the 583 quickly grew to make it our biggest seller in the amateur astronomy market. The most popular single model is the QSI 583wsg, which has an internal filter wheel like the 583ws, plus it adds an Integrated Guider Port. This allows guiding using the light from your main telescope while picking off the light from the guide star in front of the filters.

Do you personally enjoy observing?

I now enjoy it very much, although my time has been limited over the past year as our growth has accelerated. Dark nebulae tend to be my favorite objects, but more and more I find myself drawn to wide-field images that provide some context in the sky for the popular objects that most imagers focus on.

Where, in your opinion, is the hobby headed?

I think we're just at the beginning of a renaissance in small telescope astroimaging. With their high-quality equipment, powerful software, and well-understood image processing techniques, people today are producing images with 4-inch and 5-inch refractors that rival those from large professional telescopes just 20 years ago.

And now, larger telescopes that produce beautiful flat fields for use with CCDs are becoming much more affordable. The popularity and relatively low cost of high-quality DSLRs promises a steady supply of people interested in going deeper into the night sky.

Plus, astronomy is really the last major area of study where a dedicated amateur can make a real contribution to science. You're just not going to see that in, say, physics — at least, not until someone invents the backyard supercollider.

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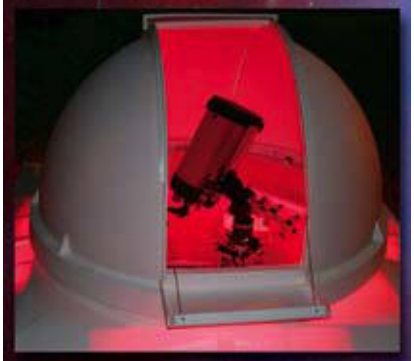

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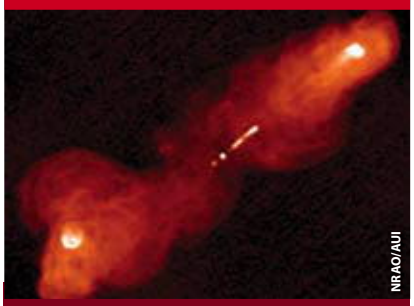

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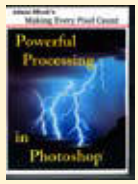

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Celestia is a space simulation program that lets you command a virtual hyperdrive spacecraft. You can orbit Mars, plunge through Saturn's rings, or travel to deep space at any speed, in any direction, and at any time throughout history. *Celestia* plots more than 2 million stars and 10,000 galaxies.

Price: $29 to $89
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[w] www.gregs-educational.info

CCD camera
Orion Telescopes and Binoculars
Watsonville, California

Orion's Parsec 8300M Astronomical Imaging Camera features a full-frame 8.3-megapixel monochrome chip, regulated dual-stage thermoelectric cooling, an internal shutter, and a 32-megabyte memory buffer. The 2" nosepiece has threads for filters, and the camera comes with USB and power cords.
Price: $2,599.95
[t] 800.447.1001
[w] www.orientelescopes.com

Mount caster set
ScopeRoller
Horseshoe Bend, Idaho

ScopeRoller's ZeroMotion caster sets let you roll your fully assembled telescope out of the garage or shed. The casters add about 4 inches (10cm) to the tripod's height and have a maximum capacity of 660 pounds (299 kg). The price listed is for a tripod that has Vixen HAL-130 legs. Twenty-five models are available.

Price: $175
[t] 208.761.5916
[w] www.scoperoller.com

12.3-inch astrograph
Officina Stellare
Thiene, Italy

Officina Stellare's UltraCRC 320 offers f/5.4 Ritchey-Chrétien optics, an Astro Sitall glass primary mirror, machined aluminum parts, and a zero expansion carbon truss structure. The telescope is 28.3 inches (72cm) long, and it weighs 55 pounds (25 kg).
Price: 12,500 Euros
[t] +39 0445 380580
[w] www.officinastellare.com

6-inch Schmidt-Cassegrain scope
Meade Instruments
Irvine, California

Meade's LT-6 f/10 telescope is a complete Schmidt-Cassegrain system that includes the AutoStar Hand Controller, a database of 30,233 objects, a die-cast aluminum mount, and a steel field tripod. The system weighs 39 pounds (17.7 kg).
Price: $999
[t] 800.626.3233
[w] www.meade.com

12.5-inch astrograph
Starizona
Tucson, Arizona

Starizona announces the Hyperion 12.5 f/8 telescope. The instrument employs a Harmer-Wynne optical design. Starizona includes an instrument rotator, a 3.5" Feathertouch focuser, and wireless control of all electronic features.
Price: $10,000
[t] 520.292.5010
[w] www.starizona.com

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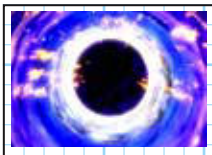
The Cosmic Grid

All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews and Liz Kruesi**

WEIRD



Black hole on board

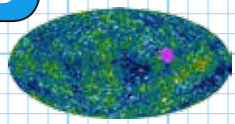
Scientists calculate a "sweet spot" for black holes, allowing spaceships to harness their energy for travel. The velocity of such vessels would be measured in units of awesome.

High chair

A Toshiba commercial depicts a balloon lifting a chair to the edge of space, all captured on the company's cameras. Everyone thinks it's cool except the guy now missing a chair.

High-hotel costs

If you'd rather travel for your vacation, the Galactic Suite Space Resort — the first space hotel — is taking reservations. Beginning in 2012, $4.4 million will get you a great view.



Galactic tug

Researchers find more evidence that something is pulling a stream of 1,400 galaxy clusters in one direction. There is even talk of this "something" being a parallel universe. That sounds just about as crazy as string theory.

When bread collides

The Large Hadron Collider suffers another fallback as a hungry bird drops its bread into the experiment and shuts it down. Something must be out to get the LHC. Maybe it's the future.

Solar scare

A scientific paper suggests our Sun isn't ideally suited for carbon-based life. Heck, Superman's been trying to tell us that for years.

Asian aliens?

Chinese shoppers spot a UFO hovering over a store's entrance. It's either aliens or the long-lost finale to the epic Beijing 2008 Olympics.

The ultimate staycation

Pretend you're aboard the International Space Station with *The Astronaut's Cookbook*. Cook some space meals and veg out in front of NASA TV.

urban DICTIONARY

Tweep it up

Urban Dictionary officially defines "space tweep" as someone who tweets about space. Because nothing's as "urban" as tweeting about space.

Salt Lake City lights

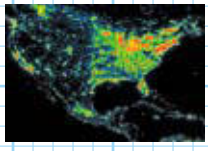
A large meteor lights up the night sky in November, leaving Utahns "terrified." That's unbelievable — they're actually called Utahns?

HOT

NOT

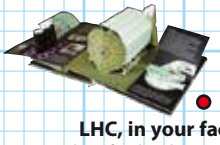
Light news

The American Medical Association officially advocates against light pollution. But you know Big Light Bulb won't take this lying down.



Rocket rocks

NASA's Ares-I rocket named *Time* magazine's best invention of the year. All right, so who at NASA bribed whom at *Time*?



LHC, in your face!

Looking for the ultimate science geek book? Papadakis Publishing has released *Voyage to the Heart of Matter* — a pop-up book about the Large Hadron Collider's ATLAS experiment and the Big Bang.

Legal aliens

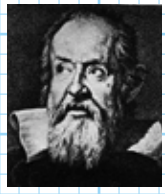
NASA invites public to help map an alien landscape and "Be a martian!" Apparently, martians look at pictures of Mars all day on their computers. With that weather, we can't blame them.

Eccentric opera

Philip Glass' 23rd opera centers on the work of Johannes Kepler and his struggle to reconcile science and religion. Plus now he gets stabbed by a Valkyrie.

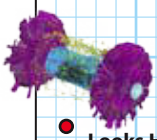
Artificial armada intelligence

A Caltech professor suggests we explore planets with an "armada" of robots that can adapt and think for themselves. Sounds good, just don't name it Skynet.



Finding Galileo

An Italian art collector finds Galileo's "lost" fingers and a tooth. And they say art and science can't mix!



Looks Hot, CERN

Neither the bird's breakfast nor the electrical problems could stop the Large Hadron Collider from finally — and we mean, finally — powering up November 20. The sabotagers from the future finally fail!

Billions and billions

Carl Sagan Day, November 7, celebrated what would have been Sagan's 75th birthday. It honors his legacy and how wonderful astronomy is. Easiest planning committee ever.

Nothin' but NASA

For those who believe NASA has been a waste of taxpayer's money, check out *Spinoff 2009*, where you can read how an adapted Hubble algorithm helps hospitals improve their scheduling issues. Hmmm, maybe that's a bad example.

Cosmic swatch

NASA scientists say the color of our universe closely matches Benjamin Moore's Ivory Tower 2157-70, a shade of beige. Way to make space itself boring, NASA.

PREDICTABLE

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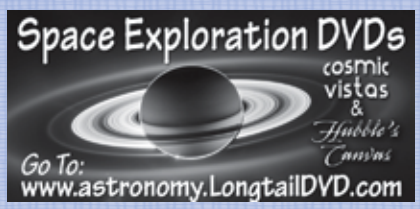
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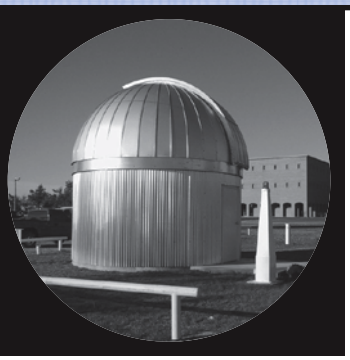

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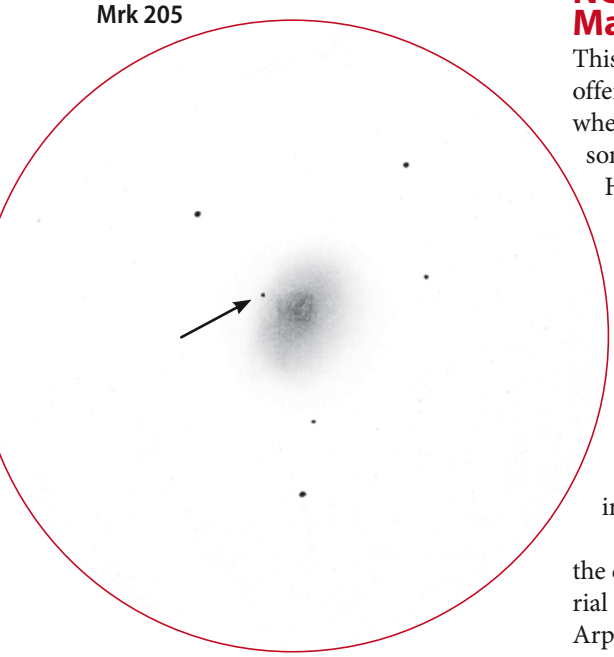
Deep-sky Showcase

Astronomy's *editor sketches two of his favorite objects.* **by David J. Eicher**

Two galaxy pairs

NGC 4319 and Mrk 205



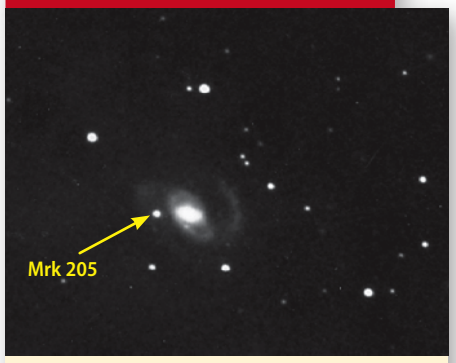
NGC 4319 and Mrk 205 (arrow) sketched by David J. Eicher using a 17.5 inch f/4.5 reflector at 222x.

NGC 4319 and Markarian 205

This pair made of a galaxy and a quasar offers one of the strangest couples anywhere in the sky. It's a celebrated twosome because in 1971 astronomer Halton C. Arp imaged what he thought was a luminous "bridge" of material between the galaxy, NGC 4319, and the quasar, Markarian 205. As calculated by their redshifts, Markarian 205 lies some 12 times farther away than its apparent neighbor galaxy. So if the two really were physically connected, Arp contended, the system of using redshifts for determining distances is wrong.

After scrutiny by many astronomers, the consensus is that no bridge of material connects the two objects, and that Arp was wrong. The pair still offers an intriguing and challenging object for large-scope owners. See if you can detect a hint of spiral structure in NGC 4319; you'll be fortunate to see Markarian 205 dimly glowing as a "star" not far from the galaxy's hub.

NGC 4319 and Mrk 205



Martin C. Germano

Designation: NGC 4319
Position: 12h22m, 75°19' (2000.0)
Constellation: Draco
Type: SB(r)ab
Magnitude: 12.8
Size: 3.0' by 2.3'
Distance: 80 million light-years

Designation: Markarian 205
Position: 12h22m, 75°19' (2000.0)
Constellation: Draco
Magnitude: 15.0
Size: stellar
Distance: 960 million light-years

M65 and M66

Rogelio Bernal Andreo

Designations: M65, NGC 3623
Position: 11h19m, 13°05' (2000.0)
Constellation: Leo
Type: SAB(rs)a
Magnitude: 9.2
Size: 9.8' by 2.9'
Distance: 32 million light-years

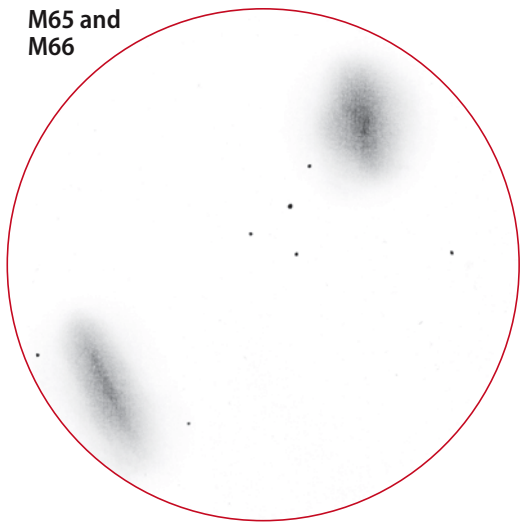
Designations: M66, NGC 3627
Position: 11h20m, 12°59' (2000.0)
Constellation: Leo
Type: SAB(s)b
Magnitude: 9.0
Size: 9.1' by 4.2'
Distance: 29 million light-years

M65 and M66

Another springtime view offers a "two for one" deal. In Leo, the bright galaxies M65 and M66 lie just 20' apart, and they are the two brightest of what is actually an extragalactic threesome. The edge-on galaxy NGC 3628 also lies nearby, and it offers a prominent equatorial dust lane. Together, these three galaxies are often nicknamed the "Leo Trio."

Small telescopes show M65 and M66 nicely. At magnitude 9.0, M66 is the brighter, and it shows a bright oval center surrounded by a faint haze of spiral arms. M65 appears fainter but is still easily visible in small scopes. The thin disk portion of this galaxy shows up well in any scope; the galaxy's hazy perimeter becomes visible in an 8-inch scope at moderate powers. Nearby NGC 3628 is a beautiful little slice of nebulosity that appears starkly edge-on.

M65 and M66



Galaxies M65 and M66 sketched by David J. Eicher using an 8-inch f/10 SCT at 70x.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 33 years.*

reader gallery

Spiral galaxy M74 (17-inch Planewave CDK17 Cassegrain telescope at f/6.8, SBIG ST-11000M CCD camera, LRGB image with exposures of 260, 180, 165, and 180 minutes, respectively) • Bob and Janice Fera, Foresthill, California

Emission nebula IC 1871 is part of the Soul Nebula (IC 1848) in Cassiopeia. The red color comes from hydrogen atoms releasing energy. (12.1-inch RC Optical Systems Ritchey-Chrétien reflector, SBIG STL-11000 CCD camera, LRGB image with exposures of 12, 2, 2, and 2 hours, respectively) • Jeff Lunglhofer, Chula Vista, California

Spiral masterpiece

Meet the grand design spiral M74 in Pisces. To find it, move your telescope 1.3° east-northeast of magnitude 3.6 Eta (η) Piscium. At a distance of 24 million light-years, stellar associations and gas clouds in this galaxy stand out well, so it's one of the few that will benefit from a nebula filter.

If you plan to observe this galaxy with a filter, use at least a 12-inch telescope to assure good light throughput. Look for M74's uneven arms, the mottled halo around the bright core, and the half-dozen stars superimposed on the galaxy.

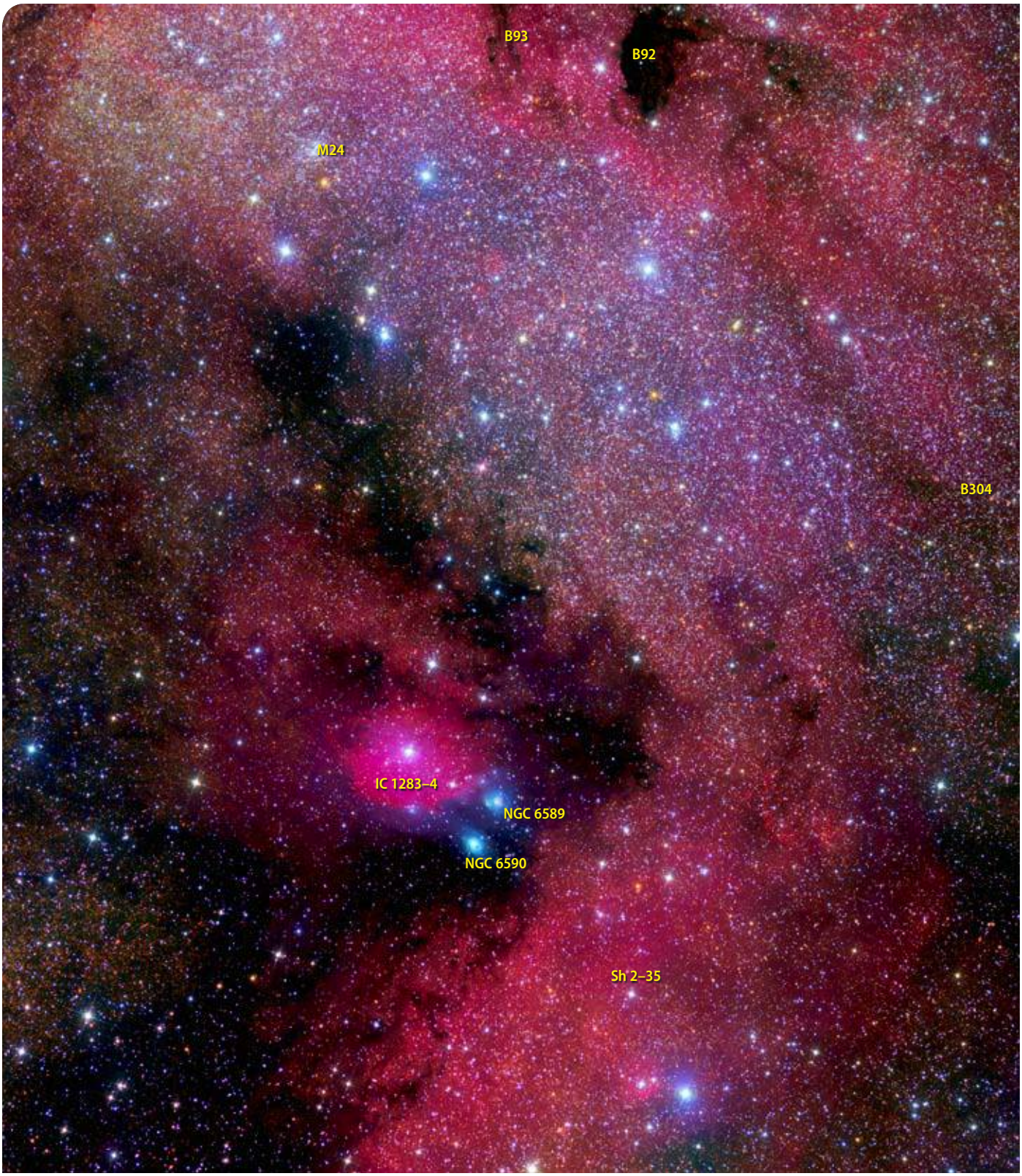
The Skull Nebula (NGC 246) in Cetus is a low-surface-brightness planetary nebula. It lies 1,600 light-years away and glows at 12th magnitude. (9.25-inch Celestron Schmidt-Cassegrain telescope at f/6.3, SBIG ST-4000XCM CCD camera, seven 10-minute exposures, stacked) • Hunter Wilson, Lexington, Ohio

Open cluster NGC 1342 in Perseus sits 5.7° west-southwest of magnitude 3.0 Epsilon (ε) Persei. It shines at magnitude 8.9 and measures 11' by 7.6'. About 100 stars are easily visible. (6.4-inch Astro-Physics AP160 StarFire EDF refractor at f/7.5, SBIG ST-10XME CCD camera, LRGB image with exposures of 45, 30, 30, and 30 minutes, respectively) • Anthony Ayiomamitis, Athens, Greece

This 180° panorama of Aphrodisias, an ancient Karian city located near Karacasu, Turkey, shows stars, Jupiter (the bright object near the center), the Milky Way, a few clouds, and a bit of light pollution from Denizli, Turkey. (4 images side by side, taken with a Canon EOS 5D digital SLR, 17mm f/2.8 fish-eye lens at f/3.5, ISO 3200, each image was a 1-minute exposure, taken September 10, 2009) • Tunç Tezel, Bursa, Turkey

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.



The region of IC 1283–4 in Sagittarius contains many wonderful nebulae of all kinds. Reddish clouds are emission nebulae of ionized hydrogen. Blue objects represent reflection nebulae made of cold gas and dust. Objects labeled with a "B" are Barnard objects, dark nebulae first cataloged by American astronomer Edward Emerson Barnard in the 1920s. (6.2-inch Astro-Physics 155EDF apochromatic refractor at f/5.4, FLI ProLine KAI-16803 CCD camera, L/Hα/RGB image with exposures of 260, 210, 140, 120, and 170 minutes, respectively) • Thomas V. Davis, Inkom, Idaho

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—Tippy D'Auria, Founder of the Winter Star Party

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